INTERFERENCE OF LIGHT

LIGHT

The physical cause, with the help of which our *eyes* experience the sensation of vision, is known as light or the form of energy, which excites our retina and produce the sensation of vision, is known as light.

PROPERTIES OF VISIBLE LIGHT

- No material medium is required for the propagation of light energy i.e. it travels even in vacuum.

- Its velocity is constant in all inertial frames i.e. it is an absolute constant. It is independent of the relative velocity between source and the observer.

- Its velocity in vacuum is maximum whose value is 3×10^8 m/s.

- It lies in the visible region of electromagnetic spectrum whose wavelength range is from 4000 Å to 8000 Å.

- Its energy is of the order of eV.

- It propagates in straight line.

- It exhibits the phenomena of reflection, refraction, interference, diffraction, polarisation and double refraction.

- It can emit electrons from metal surface i.e. it can produce photoelectric effect.

- It produces thermal effect and exerts pressure when incident upon a surface. It proves that light has momentum and energy.

- Its velocity is different in different media. In rarer medium it is more and in denser medium it is less.

- Light energy propagates via two processes.

    (a)   The particles of the medium carry energy from one point of the medium to another.

    (b)   The particles transmit energy to the neighbouring particles and in this way energy propagates in the form of a disturbance.

DIFFERENT THEORIES OF LIGHT

- Newton's corpuscular theory of light.
- Maxwell's electromagnetic theory of light.
- De-Broglie's dual theory of light.
- Hygen's wave theory of light.
- Plank's Quantum theory of light.

NEWTON'S CORPUSCULAR THEORY OF LIGHT

This theory was enuciated by Newton.

- **Characteristics of the theory**

    (i)   Extremely minute, very light and elastic particles are being constantly emitted by all luminous bodies (light sources) in all directions

    (ii)   These corpuscles travel with the speed of light..

    (iii)   When these corpuscles strike the retina of our eye then they produce the sensation of vision.

    (iv)   The velocity of these corpuscles in vacuum is 3×10^8 m/s.

    (v)   The different colours of light are due to different size of these corpuscles.

    (vi)   The rest mass of these corpuscles is zero.

    (vii)   The velocity of these corpuscles in an isotropic medium is same in all directions but it changes with the change of medium.

    (viii) These corpuscles travel in straight lines.

    (ix)   These corpuscles are invisible.

• **The phenomena explained by this theory**

(i)   Reflection and refraction of light.   (ii)   Rectilinear propagation of light.

(iii)   Existence of energy in light.

• **The phenomena not explained by this theory**

(i)   Interference, diffraction, polarisation, double refraction and total internal reflection.

(ii)   Velocity of light being greater in rarer medium than that in a denser medium.

(iii)   Photoelectric effect and Crompton effect.

WAVE THEORY OF LIGHT

This theory was enunciated by Hygen in a hypothetical medium known as luminiferrous ether.

Ether is that imaginary medium which prevails in all space, in isotropic, perfectly elastic and massless.

The different colours of light are due to different wave lengths of these waves.

The velocity of light in a medium is constant but changes with change of medium.

This theory is valid for all types of waves.

(i)   The locus of all ether particles vibrating in same phase is known as wavefront.

(ii)   Light travels in the medium in the form of wavefront.

(iii)   When light travels in a medium then the particles of medium start vibrating and consequently a disturbance is created in the medium.

(iv)   Every point on the wave front becomes the source of secondary wavelets. It emits secondary wavelets in all directions which travel with the speed of light (v),

The tangent plane to these secondary wavelets represents the new position of wave front.

(a)   (b)
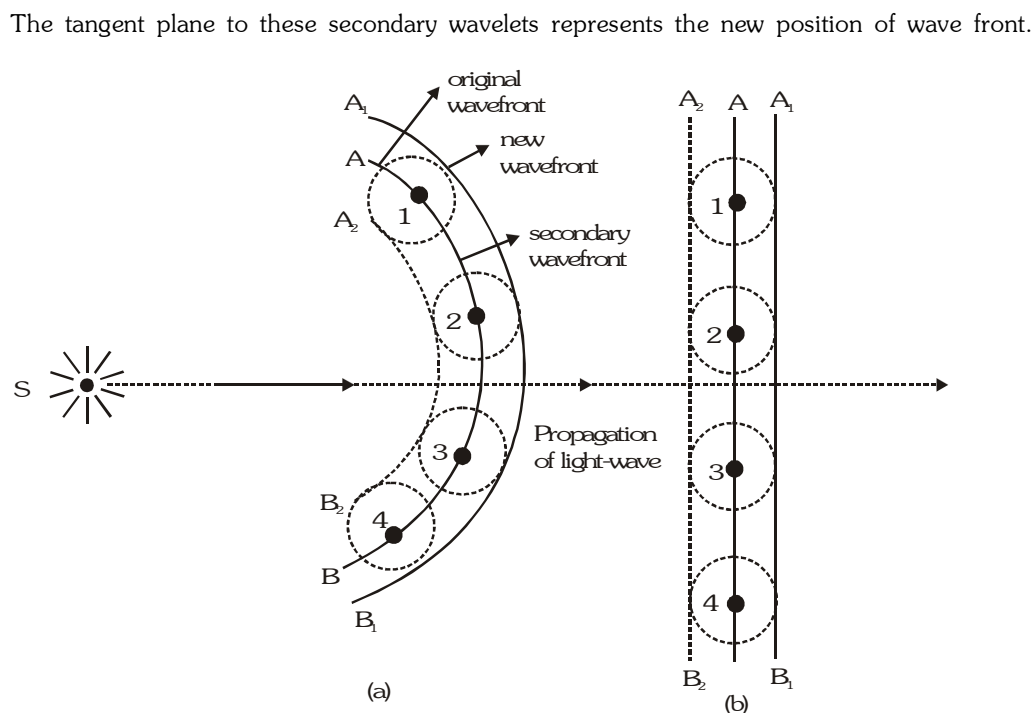
The phenomena explained by this theory

(i)   Reflection, refraction, interference, diffraction, polarisation and double refraction.

(ii)   Rectilinear propagation of light.

(iii)   Velocity of light in rarer medium being grater than that in denser medium.

Phenomena not explained by this theory

(i)   Photoelectric effect, Compton effect and Raman effect.

(ii)   Backward propagation of light.

E

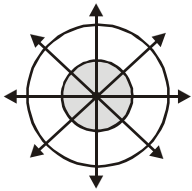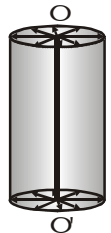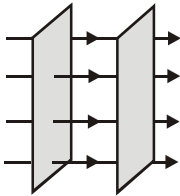## WAVE FRONT, VARIOUS TYPES OF WAVE FRONT AND RAYS

- **Wavefront**

    The locus of all the particles vibrating in the same phase is known as wavefront.

- **Types of wavefront**

    The shape of wavefront depends upon the shape of the light source originating that wavefront. On the basis of there are three types of wavefront.

Comparative study of three types of wavefront

S.No.	Wavefront	Shape of light source	Diagram of shape of wavefront	Variation of amplitude with distance	Variation of intensity with distance
1.	Spherical	Point source		$A \propto \dfrac{1}{d}$ or $A \propto \dfrac{1}{r}$	$I \propto \dfrac{1}{r^2}$
2.	cylindrical	Linear or slit		$A \propto \dfrac{1}{\sqrt{d}}$ or $A \propto \dfrac{1}{\sqrt{r}}$	$I \propto \dfrac{1}{r}$
3.	Plane	Extended large source situated at very large distance		$A = $ constant	$I = $ constant

CHARACTERISTIC OF WAVEFRONT

(a)   The phase difference between various particles on the wavefront is zero.

(b)   These wavefronts travel with the speed of light in all directions in an isotropic medium.

(c)   A point source of light always gives rise to a spherical wavefront in an isotropic medium.

(d)   In an anisotropic medium it travels with different velocities in different directions.

(e)   Normal to the wavefront represents a ray of light.

(f)   It always travels in the forward direction of the medium.

RAY OF LIGHT

The path of the light energy from one point to another is known as a ray of light.

(a)   A line drawn at right angles to the wavefront is defined as a ray of light, which is shown by arrows in previous diagram of shape of wavefront.

(b)   It represents the direction of propagation of light.

INTERFERENCE OF LIGHT

When two light waves of same frequency with zero initial phase difference or constant phase difference superimpose over each other, then the resultant amplitude (or intensity) in the region of superimposition is different from the amplitude (or intensity) of individual waves.

This modification in intensity in the region of superposition is called interference.

(a)   Constructive   interference

When resultant intensity is greater than the sum of two individual wave intensities $[I > (I_1 + I_2)]$, then the interference is said to be constructive.

(b)   Destructive   interference

When the resultant intensity is less than the sum of two individual wave intensities $[I < (I_1 + I_2)]$, then the interference is said to destructive.

There is no violation of the law of conservation of energy in interference. Here, the energy from the points of minimum energy is shifted to the points of maximum energy.

TYPES OF SOURCES

- **Coherent source**

Two sources are said to be coherent if they emit light waves of the same wavelength and start with same phase or have a constant phase difference.

Note : Laser is a source of monochromatic light waves of high degree of coherence.

Main points :

1. They are obtained from the same single source.

2. Their state of polarization is the same

- **Incoherent source**

Two independent monochromatic sources, emit waves of same wavelength.

But the waves are not in phase. So they are incoherent. This is because, atoms cannot emit light waves in same phase and these sources are said to be incoherent sources. By using two independent laser beams it has been possible to record the interference pattern.
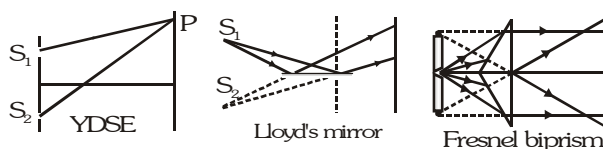

Independent Source
(non-coherent source)
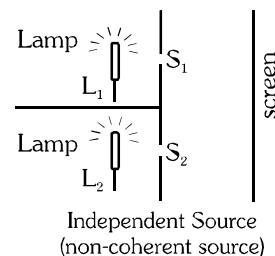
METHOD FOR OBTAINING COHERENT SOURCE

- **Division of wave front**

In this method, the wavefront is divided into two or more parts by use of mirrors, lenses or prisms.

Example : Young's double slit experiment. Fresnel's Biprism and Lloyd's single mirror method.

- **Division of amplitude**

The amplitude of incoming beam is divided into two or more parts by partial reflection or refraction. These divided parts travel different paths and are finally brought together to produce interference.

Example : The brilliant colour seen in a thin film of transparent material like soap film, oil film, Michelson's Interferro Meter, Newtons' ring etc.

Newton's rings
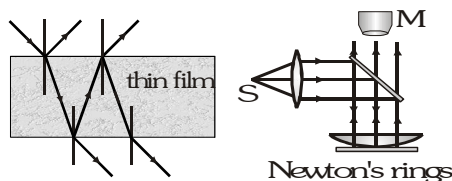
Condition for sustained interference

To obtain the stationary interference pattern, the following conditions must be fulfilled :

(a)   The two sources should be coherent, i.e., they should vibrate in the same phase or there should be a constant phase difference between them.

(b)   The two sources must emit continuously waves of same wavelength and frequency.

(c)   The separation between two coherent sources should be small.

(d)   The distance of the screen from the two sources should be small.

(e)   For good contrast between maxima and minima, the amplitude of two interfering waves should be as nearly equal as possible and the background should be dark.

(f)   For a large number of fringes in the field of view, the sources should be narrow and monochromatic.

ANALYSIS OF INTERFERENCE OF LIGHT

When two light waves having same frequency and equal or nearly equal amplitude are moving in the same direction, They superimpose each other, at some point the intensity of light is maximum and at some point it is minimum this phenomenon is known as interference of light.

Let two waves having amplitude a_1 and a_2 and same frequency, same phase difference ϕ superpose. Let their displacement are : $y_1 = a_1 \sin \omega t$ and $y_2 = a_2 \sin (\omega t + \phi)$

By principle of superposition.

$$y = y_1 + y_2 = a_1 \sin \omega t + a_2 \sin (\omega t + \phi) = a_1 \sin \omega t + a_2 [\sin \omega t \cos \phi + \cos \omega t \sin \phi]$$

$$= \sin \omega t (a_1 + a_2 \cos \phi) + a_2 \cos \omega t \sin \phi$$

Let, $a_1 + a_2 \cos \phi = A \cos \theta$ and $a_2 \sin \phi = A \sin \theta$

Hence $y = A \sin \omega t \cos \theta + A \cos \omega t \sin \theta = A \sin (\omega t + \theta)$

Resultant amplitude $A = \sqrt{a_1^2 + a_2^2 + 2a_1 a_2 \cos \phi}$ and Phase angle $\theta = \tan^{-1} \dfrac{a_2 \sin \phi}{a_1 + a_2 \cos \phi}$

Intensity $\propto$ (Amplitude)^2 $\Rightarrow I \propto A^2 \Rightarrow$ $I = KA^2$ so $I_1 = Ka_1^2$ & $I_2 = Ka_2^2$ $\therefore$ $I = I_1 + I_2 + 2\sqrt{I_1} \sqrt{I_2} \cos \phi$

here, $2\sqrt{I_1} \sqrt{I_2} \cos \phi$ is known as interference factor.
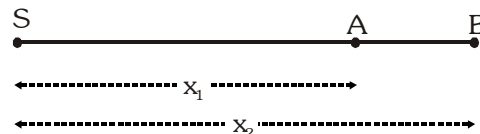
- If the distance of a source from two points A and B is x_1 and x_2 then

Path difference $\delta = x_2 - x_1$

Phase difference $\phi = \dfrac{2\pi}{\lambda} (x_2 - x_1) \Rightarrow \phi = \dfrac{2\pi}{\lambda} \delta$

Time difference $\Delta t = \dfrac{\phi}{2\pi} t$

$$\dfrac{\text{Phase difference}}{2\pi} = \dfrac{\text{Path difference}}{\lambda} = \dfrac{\text{Time difference}}{T} \Rightarrow \dfrac{\phi}{2\pi} = \dfrac{\delta}{\lambda} = \dfrac{\Delta t}{T}$$

TYPES OF INTERFERENCE

Constructive Interference

When both waves are in same phase. So phase difference is an even multiple of $\pi \Rightarrow \phi = 2 n\pi$; n = 0,1,2 ...

- When path difference is an even multiple of $\dfrac{\lambda}{2}$

$$\because \frac{\phi}{2\pi} = \frac{\delta}{\lambda} \Rightarrow \frac{2n\pi}{2\pi} = \frac{\delta}{\lambda} \Rightarrow \delta = 2n\left(\frac{\lambda}{2}\right) \Rightarrow \delta = n\lambda \text{ (where n = 0,1,2...)}$$

- When time difference is an even multiple of $\dfrac{T}{2}$ $\therefore \Delta t = 2n\left(\dfrac{T}{2}\right)$

- In this condition the resultant amplitude and Intensity will be maximum.

$$A_{max} = (a_1 + a_2) \Rightarrow I_{max} = I_1 + I_2 + 2\sqrt{I_1}\sqrt{I_2} = (\sqrt{I_1} + \sqrt{I_2})^2$$

Destructive Interference

When both the waves are in opposite phase. So phase difference is an odd multiple of π .

$$\phi = (2n-1)\pi \ ; \ n = 1, 2 ...$$

- When path difference is an odd multiple of $\dfrac{\lambda}{2}$, $\delta = (2n-1)\dfrac{\lambda}{2}$, n = 1, 2 ...

- When time difference is an odd multiple of $\dfrac{T}{2}$, $\Delta t = (2n-1)\dfrac{T}{2}$, (n=1,2...)

In this condition the resultant amplitude and intensity of wave will be minimum.

$$A_{min} = (a_1 - a_2) \Rightarrow I_{min} = (\sqrt{I_1} - \sqrt{I_2})^2$$

GOLDEN KEY POINTS

- Interference follows law of conservation of energy.

- Average Intensity $I_{av} = \dfrac{I_{max} + I_{min}}{2} = I_1 + I_2 = a_1^2 + a_2^2$

- Intensity $\propto$ width of slit $\propto$ (amplitude)^2 $\Rightarrow$ $I \propto w \propto a^2 \Rightarrow \dfrac{I_1}{I_2} = \dfrac{w_1}{w_2} = \dfrac{a_1^2}{a_2^2}$

- $\dfrac{I_{max}}{I_{min}} = \left[\dfrac{\sqrt{I_1} + \sqrt{I_2}}{\sqrt{I_1} - \sqrt{I_2}}\right]^2 = \left[\dfrac{a_1 + a_2}{a_1 - a_2}\right]^2 = \left[\dfrac{a_{max}}{a_{min}}\right]^2$

- Fringe visibility $V = \dfrac{I_{max} - I_{min}}{I_{max} + I_{min}} \times 100\%$ when $I_{min} = 0$ then fringe visibility is maximum

  i.e. when both slits are of equal width the fringe visibility is the best and equal to 100%.

Example

If two waves represented by $y_1 = 4 \sin \omega t$ and $y_2 = 3 \sin (\omega t + \frac{\pi}{3})$ interfere at a point. Find out the amplitude of the resulting wave.

Solution

Resultant amplitude $A = \sqrt{a_1^2 + a_2^2 + 2a_1 a_2 \cos\phi} = \sqrt{(4)^2 + (3)^2 + 2.(4)(3)\cos\frac{\pi}{3}} \Rightarrow A \simeq 6$

Example

Two beams of light having intensities I and 4I interferer to produce a fringe pattern on a screen. The phase difference between the beam is $\frac{\pi}{2}$ at point A and 2π at point B. Then find out the difference between the resultant intensities at A and B.

Solution

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

Resultant intensity at point A is $I_A = I + 4I + 2\sqrt{I} \sqrt{4I} \cos\frac{\pi}{2} = 5I$

Resultant intensity at point B, $I_B = I + 4I + 2\sqrt{I} \sqrt{4I} \cos 2\pi = 9I$ ($\because \cos 2\pi = 1$) $\therefore I_B - I_A = 9I - 5I \Rightarrow 4I$

Example

In interference pattern, if the slit widths are in the ratio 1:9. Then find out the ratio of minimum and maximum intensity.

Solution

Slit width ratio

$\dfrac{w_1}{w_2} = \dfrac{1}{9} \because \dfrac{I_1}{I_2} = \dfrac{w_1}{w_2} = \dfrac{a_1^2}{a_2^2} = \dfrac{1}{9} \Rightarrow \dfrac{a_1}{a_2} = \dfrac{1}{3} \Rightarrow 3a_1 = a_2 \therefore \dfrac{I_{min}}{I_{max}} = \dfrac{(a_1 - a_2)^2}{(a_1 + a_2)^2} = \dfrac{(a_1 - 3a_1)^2}{(a_1 + 3a_1)^2} = \dfrac{4}{16} = 1:4$

Example

The intensity variation in the interference pattern obtained with the help of two coherent source is 5% of the average intensity. Find out the ratio of intensities of two sources.

Solution

$\dfrac{I_{max}}{I_{min}} = \dfrac{105}{95} = \dfrac{21}{19} \Rightarrow \dfrac{(a_1 + a_2)^2}{(a_1 - a_2)^2} = \dfrac{21}{19} \Rightarrow \dfrac{a_1 + a_2}{a_1 - a_2} = \sqrt{\dfrac{21}{19}} = 1.05 \Rightarrow a_1 + a_2 = 1.05\, a_1 - 1.05\, a_2$

$0.05\, a_1 = 2.05\, a_2 \Rightarrow \dfrac{a_1}{a_2} = \dfrac{2.05}{0.05} = \dfrac{41}{1} \quad \therefore \dfrac{I_1}{I_2} = \dfrac{a_1^2}{a_2} = \dfrac{1680}{1}$

Example

Waves emitted by two identical sources produces intensity of K unit at a point on screen where path difference between these waves is λ, calculate the intensity at that point on screen at which path difference is $\frac{\lambda}{4}$.

Solution

$\phi_1 = \dfrac{2\pi\delta}{\lambda} \Rightarrow \dfrac{2\pi}{\lambda} \times \lambda = 2\pi$ and $\phi_2 = \dfrac{2\pi}{\lambda} \times \dfrac{\lambda}{4} = \dfrac{\pi}{2}$ $\quad I_1 = I_0 + I_0 + 2\sqrt{I_0}\sqrt{I_0} \cos 2\pi = 4I_0$

and $I_2 = I_0 + I_0 + 2\sqrt{I_0}\sqrt{I_0} \dfrac{\cos 2\pi}{2} = 2I_0 \quad \therefore \dfrac{I_1}{I_2} = \dfrac{4I_0}{2I_0} = 2 \quad \Rightarrow I_2 = \dfrac{I_1}{2} = \dfrac{K}{2}$ unit [$\because I_1 = K$ unit]

YOUNG'S DOUBLE SLIT EXPERIMENT (YDSE)

According to Huygen, light is a wave. It is proved experimentally by YDSE.

S is a narrow slit illuminated by a monochromatic source of light sends wave fronts in all directions. Slits S_1 and S_2 become the source of secondary wavelets which are in phase and of same frequency. These waves are superimposed on each other gave rise to interference. Alternate dark and bright bands are obtained on a screen (called interference fringes) placed certain distance from the plane of slit S_1 and S_2. Central fringe is always bright (due to path from S_1O and S_2O centre is equal) called central maxima.
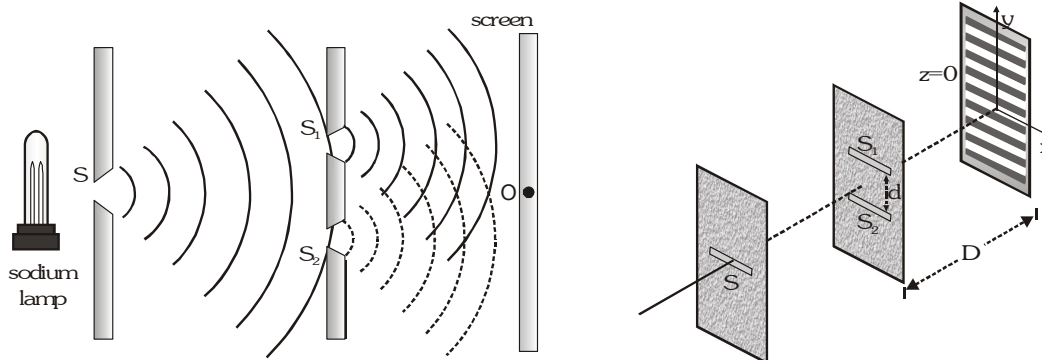
Energy is conserved in interference. This indicated that energy is redistributed from destructive interference region to the constructive interference region .

- If one of the two slit is closed. The interference pattern disappears. It shows that two coherent sources are required to produce interference pattern.

- If white light is used as parent source, then the fringes will be coloured and of unequal width.

(i) Central fringe will be white.

(ii) As the wave length of violet colour is least, so fringe nearest to either side of the central white fringe is violet and the fringe farthest from the central white fringe is red.

CONDITION FOR BRIGHT AND DARK FRINGES

Bright Fringe

D = distance between slit and screen,   d = distance between slit S_1 and S_2

Bright fringe occurs due to constructive interference.

$\because$ For constructive interference path difference should be even multiple of $\dfrac{\lambda}{2}$
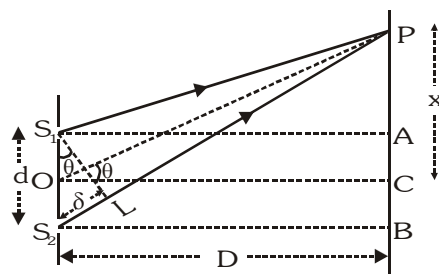
$\therefore$ Path difference $\delta = PS_2 - PS_1 = S_2L = (2n)\dfrac{\lambda}{2}$

In ΔPCO $\tan\theta = \dfrac{x_n}{D}$; In ΔS_1S_2L $\sin\theta = \dfrac{\delta}{d}$

$\delta = n\lambda$ for bright fringes

If θ is small then $\tan\theta \simeq \sin\theta \Rightarrow \dfrac{x_n}{D} = \dfrac{\delta}{d}$

The distance of nth bright fringe from the central bright fringe $x_n = n\dfrac{D\lambda}{d}$

E

Dark Fringe

Dark fringe occurs due to destructive interference.

$\because$ For destructive interference path difference should be odd multiple of $\dfrac{\lambda}{2}$.

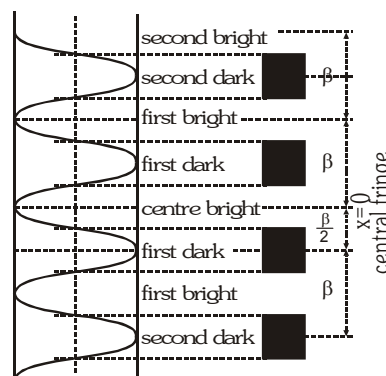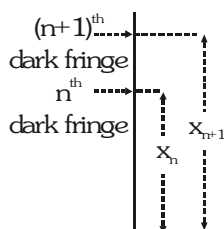$\therefore$ Path difference $\delta = (2m-1)\,\dfrac{\lambda}{2}$

The distance of the mth dark fringe from the central bright fringe $x_m = \dfrac{(2m-1)D\lambda}{2d}$
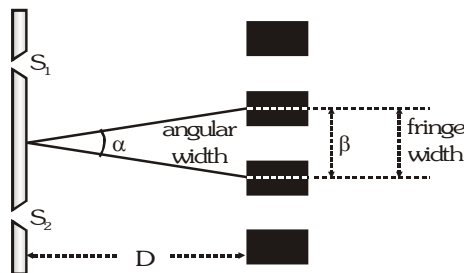
FRINGE WIDTH

The distance between two successive bright or dark fringe is known as fringe width.

$$\beta = x_{n+1} - x_n = \dfrac{(n+1)D\lambda}{d} - \dfrac{nD\lambda}{d}$$

Fringe Width $\quad \beta = \dfrac{D\lambda}{d}$

ANGULAR FRINGE WIDTH

Angular Fringe Width $\qquad \alpha = \dfrac{\beta}{D}, \quad \alpha = \dfrac{\lambda}{d} \quad \left[\because \dfrac{\beta}{D} = \dfrac{\lambda}{d}\right]$

• The distance of nth bright fringe from the central bright fringe $x_n = \dfrac{n\lambda D}{d} = n\beta$

• The distance between n_1 and n_2 bright fringe $x_{n_2} - x_{n_1} = n_2\dfrac{\lambda D}{d} - n_1\dfrac{\lambda D}{d} = (n_2 - n_1)\beta$

• The distance of mth dark fringe from central fringe $x_m = \dfrac{(2m-1)D\lambda}{2d} = \dfrac{(2m-1)\beta}{2}$

• The distance of nth bright fringe from m^{th} dark fringe $x_n - x_m = n\dfrac{D\lambda}{d} - \dfrac{(2m-1)D\lambda}{2d} = n\beta - \dfrac{(2m-1)\beta}{2}$

$$x_n - x_m = \left[n - \dfrac{(2m-1)}{2}\right]\beta$$

GOLDEN KEY POINTS

- If the whole apparatus is immersed in a liquid of refractive index μ, then wavelength of light
  $\lambda' = \dfrac{\lambda}{\mu}$ since $\mu > 1$ so $\lambda' < \lambda$ $\Rightarrow$ wavelength will decrease. Hence fringe width ($\beta \propto \lambda$) will decrease
  $\Rightarrow$ fringe width in liquid $\beta' = \beta/\mu$ angular width will also decrease.

- With increase in distance between slit and screen D, angular width of maxima does not change, fringe width β increase linearly with D but the intensity of fringes decreases.

- If an additional phase difference of π is created in one of the wave then the central fringe become dark.

- When wavelength λ_1 is used to obtain a fringe n_1. At the same point wavelength λ_2 is required to obtain a fringe n_2 then $n_1 \lambda_1 = n_2 \lambda_2$

- When waves from two coherent sources S_1 and S_2 interfere in space the shape of the fringe is hyperbolic with foci at S_1 and S_2.

Example

Laser light of wavelength 630 nm incident on a pair of slits produces an interference pattern in which the bright fringes are separated by 8.1 mm. A second light produces an interference pattern in which the fringes are separated by 7.2 mm. Calculate the wavelength of the second light.

Solution

Fringe separation is given by $\beta = \dfrac{\lambda D}{d}$ i.e. $\dfrac{\beta_2}{\beta_1} = \dfrac{\lambda_2}{\lambda_1} \Rightarrow \lambda_2 = \dfrac{\beta_2}{\beta_1} \times \lambda_1 = \dfrac{7.2}{8.1} \times 630 = 560$ nm

Example

A double slit is illuminated by light of wave length 6000Å. The slit are 0.1 cm apart and the screen is placed one metre away. Calculate :

(i)   The angular position of the 10th maximum in radian and

(ii)   Separation of the two adjacent minima.

Solution

(i) $\lambda = 6000$ Å $= 6 \times 10^{-7}$ m, $d = 0.1$ cm $= 1 \times 10^{-3}$ m, $D = 1$m, $n = 10$

Angular position $\theta_n = \dfrac{n\lambda}{d} = \dfrac{10 \times 6 \times 10^{-7}}{10^{-3}} = 6 \times 10^{-3}$ rad.

(ii)   Separation between two adjacent minima = fringe width β

$\beta = \dfrac{\lambda D}{d} = \dfrac{6 \times 10^{-7} \times 1}{1 \times 10^{-3}} = 6 \times 10^{-4}$ m = 0.6 mm

Example

In Young's double slit experiment the fringes are formed at a distance of 1m from double slit of separation 0.12 mm. Calculate

(i)   The distance of 3rd dark band from the centre of the screen.

(ii)   The distance of 3rd bright band from the centre of the screen, given $\lambda = 6000$Å

Solution

(i)   For m^{th} dark fringe $x'_m = (2m-1)\dfrac{D\lambda}{2d}$ given, $D = 1$m $= 100$ cm, $d = 0.12$ mm $= 0.012$ cm

$x'_3 = \dfrac{(2 \times 3 - 1) \times 100 \times 6 \times 10^{-7}}{2 \times 0.012} = 1.25$ cm [$\because$ m = 3 and $\lambda = 6 \times 10^{-7}$ m]

(ii)   For n^{th} bright fringe $x_n = \dfrac{nD\lambda}{d} \Rightarrow x_3 = \dfrac{3 \times 100 \times 6 \times 10^{-7}}{0.012} = 1.5 \times 10^{-2}$ m = 1.5 cm [$\because$ n = 3]

E

Example

In Young's double slit experiment the two slits are illuminated by light of wavelength 5890Å and the distance between the fringes obtained on the screen is 0.2 . The whole apparatus is immersed in water, then find out angular fringe width, (refractive index of water = $\dfrac{4}{3}$).

Solution

$$\alpha_{air} = \frac{\lambda}{d} \Rightarrow \alpha_{air} = 0.2 \ \Rightarrow \alpha \propto \lambda \Rightarrow \frac{\alpha_w}{\alpha_{air}} = \frac{\lambda_w}{\lambda_{air}} \Rightarrow \lambda_w = \frac{\lambda_{air}}{\mu} \Rightarrow \alpha_w = \frac{\alpha_{air}\,\lambda}{\mu.\lambda} = \frac{0.2 \times 3}{4} = 0.15$$

Example

The path difference between two interfering waves at a point on screen is 171.5 times the wavelength. If the path difference is 0.01029 cm. Find the wavelength.

Solution

Path difference = $171.5\,\lambda = \dfrac{343}{2}\lambda$ = odd multiple of half wavelength . It means dark finge is observed

According to question $0.01029 = \dfrac{343}{2}\lambda \ \Rightarrow \lambda = \dfrac{0.01029 \times 2}{343} = 6 \times 10^{-5}\,cm \ \Rightarrow \lambda = 6000\ Å$

Example

In young's double slit interference experiment, the distance between two sources is $0.1/\pi$ mm. The distance of the screen from the source is 25 cm. Wavelength of light used is 5000Å. Then what is the angular position of the first dark fringe ?

Solution

The angular position $\theta = \dfrac{\beta}{D} = \dfrac{\lambda}{d}$ $(\because \ \beta = \dfrac{\lambda D}{d})$ The first dark fringe will be at half the fringe width from the mid point of central maximum. Thus the angular position of first dark fringe will be-

$$\alpha = \frac{\theta}{2} = \frac{1}{2}\left[\frac{\lambda}{d}\right] = \frac{1}{2}\left[\frac{5000 \times \pi}{.1 \times 10^{-3}} \times 10^{-10}\right]\frac{180}{\pi} = 0.45 \ .$$

FRESNEL'S BIPRISM

It is an optical device to obtain two coherent sources by refraction of light. It is prepared by rubbing an optically pure glass plate slightly on two sides so that each angle of prism is generally $\dfrac{1^{\circ}}{2}$ or 1 . The fringes of equal width are observed in the limited region MN due to superposition.
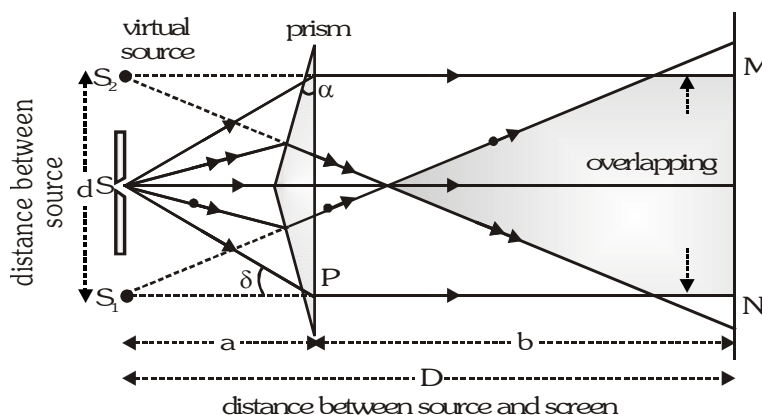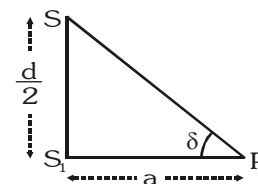
Distance between source and biprism = a

Distance between biprism and eye piece (screen) = b

The distance between source and screen D = a + b

Refracting angle = α , refractive index of the material of prism = μ

The distance between two coherent source = d

From ΔSS_1P $\tan\delta = \dfrac{d/2}{a}$ for very-very small δ hence $\tan\delta = \delta$ so $\delta = \dfrac{d}{2a} \Rightarrow$ d = 2aδ

For prism $\delta = (\mu-1)\alpha$ $\therefore$ d = 2a$(\mu-1)\alpha$, Fringe width $\beta = \dfrac{\lambda D}{d}$ $\therefore$ $\beta = \dfrac{(a+b)\lambda}{2a(\mu-1)\alpha}$

• **To calculate the value of d by displacement method**

In this method a convex lens is placed between prism and screen. The lens is adjusted in two position L_1 and L_2 and image is obtained on screen. Let d_1 an d_2 be the real image in these two cases.

The distance d between the virtual source $d = \sqrt{d_1 d_2}$ Fringe width $\beta = \dfrac{(a+b)\lambda}{\sqrt{d_1 d_2}}$

displacement method
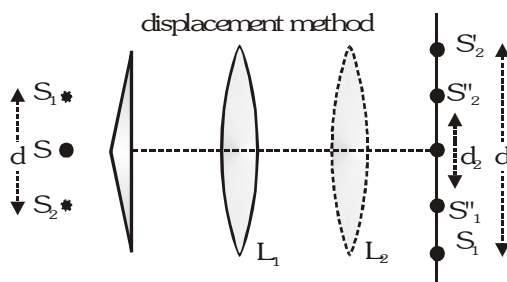
GOLDEN KEY POINTS

• If the fresnel biprism experiment is performed in water instead of air then

(i) Fringe width in water increases $\left[\beta_w = \dfrac{\mu_g - 1}{\mu_g - \mu_w}\beta_{air}\right]$ $\beta_w = 3\,\beta_{air}$ $\left[\because \mu_g = \dfrac{3}{2}, \mu_w = \dfrac{4}{3}\right]$

(ii) Separation between the two virtual sources decreases.

(but in Young's double slit experiment it does not change.)

$\because d_{air} =$ 2 a $(\mu_g - 1)\alpha$ $\therefore d_w = 2$ a $(_w\mu_g - 1)\alpha$ $\Rightarrow$ $d_w = 2$ a $\left[\dfrac{\mu_g}{\mu_w} - 1\right]\alpha$

$\therefore \dfrac{d_w}{d_{air}} = \dfrac{\dfrac{\mu_g}{\mu_w} - 1}{\mu_g - 1} = \dfrac{\dfrac{3/2}{4/3} - 1}{3/2 - 1} = \dfrac{1}{4} \Rightarrow$ $d_w = \dfrac{1}{4} d_{air}$

• If we use white light instead of monochromatic light then coloured fringes of different width are obtained. Central fringe is white.

• With the help of this experiment the wavelength of monochromatic light, thickness of thin films and their refractive index and distance between apparent coherent sources can be determined.

Example

Fringes are obtained with the help of a biprism in the focal plane of an eyepiece distant 1m from the slit. A convex lens produces images of the slit in two position between biprism and eyepiece. The distances between two images of the slit in two positions are 4.05×10^{-3} m and 2.9×10^{-3} m respectively. Calculate the distance between the slits.

Solution

$$d = \sqrt{d_1 d_2} = \sqrt{4.05 \times 10^{-3} \times 2.9 \times 10^{-3}} = 3.43 \times 10^{-3} \text{ m}$$

Example

In fresnel's biprism experiment a mica sheet of refractive index 1.5 and thickness 6×10^{-6} m is placed in the path of one of interfering beams as a result of which the central fringe gets shifted through five fringe widths. Then calculate the wavelength of light.

Solution

$$x = \frac{(\mu -1)t\beta}{\lambda} = \frac{(1.5-1)t\beta}{\lambda} \text{ but, } t = 5\beta \quad \therefore \quad 5\beta = \frac{0.5 \; t\beta}{\lambda} \Rightarrow \lambda = \frac{t}{10} = \frac{6 \times 10^{-6}}{10} = 6000\text{Å}$$

Example

A whole biprism experiment is immersed in water. If the fringe width in air is β_a and refractive index of biprism material and water are 1.5 and 1.33 respectively. Find the value of the fringe width.

Solution

$$\beta_w = \frac{\mu_g -1}{\mu_g - \mu_w}\beta_a = \frac{\dfrac{3}{2}-1}{\dfrac{3}{2}-\dfrac{4}{2}} = 3\beta_a$$

Example

In fresnel's biprism experiment the distance between the source and the screen is 1m and that between the source and biprism is 10 cm. The wavelength of light used is 6000Å. The fringe width obtained is 0.03 cm and the refracting angle of biprism is 1°. Then calculate the refractive index of the material of biprism.

Solution

$$\beta = \frac{D\lambda}{2a(\mu -1)\alpha} \quad \therefore (\mu -1) = \frac{D\lambda}{2a\beta_\alpha} = \frac{1 \times 6 \times 10^{-7} \times 180}{2 \times 0.1 \times 3 \times 10^{-4} \times 3.14} \Rightarrow (\mu -1) = 0.573 \Rightarrow \mu = 1.573$$

THICKNESS OF THIN FILMS

When a glass plate of thickness t and refractive index μ is placed in front of the slit in YDSE then the central fringe shifts towards that side in which glass plate is placed because extra path difference is introduced by the glass plate. In the path $S_1 P$ distance travelled by wave in air = $S_1 P - t$

E
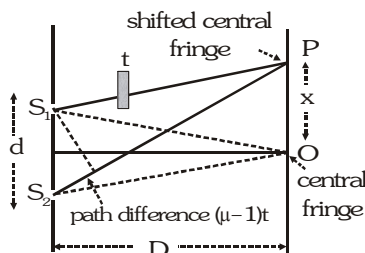
Distance travelled by wave in the sheet = t

Time taken by light to reach up to point P will be same from S_1 and S_2

$$\frac{S_2P}{c} = \frac{S_1P - t}{c} + \frac{t}{c/\mu} \Rightarrow \frac{S_2P}{c} = \frac{S_1P + (\mu-1)t}{c} \Rightarrow S_2P = S_1P + (\mu-1)t \Rightarrow S_2P - S_1P = (\mu-1)t$$

Path difference = $(\mu-1)t \Rightarrow$ Phase difference $\phi = \frac{2\pi}{\lambda}(\mu-1)t$

Distance of shifted fringe from central fringe $x = \frac{D(\mu-1)t}{d} \quad \left[\because \frac{xd}{D} = (\mu-1)t\right]$

$\therefore \quad x = \frac{\beta(\mu-1)t}{\lambda}$ and $\beta = \frac{D\lambda}{d}$ \qquad Number of fringes displaced = $\frac{(\mu-1)t}{\lambda}$

Example

When a mica sheet of thickness 7 microns and $\mu = 1.6$ is placed in the path of one of interfering beams in the biprism experiment then the central fringe gets at the position of seventh bright fringe. What is the wavelength of light used ?

Solution

$$\lambda = \frac{(\mu-1)t}{n} = \frac{(1.6-1)\,7\times10^{-6}}{7} = 6 \quad 10^{-7} \text{ meter}$$

GOLDEN KEY POINTS

- If a glass plate of refractive index μ_1 and μ_2 having same thickness t is placed in the path of ray coming from S_1 and S_2 then path difference $x = \frac{D}{d}(\mu_1 - \mu_2)t$

- Distance of displaced fringe from central fringe $x = \frac{\beta(\mu_1 - \mu_2)t}{\lambda} \qquad \because \frac{\beta}{\lambda} = \frac{D}{d}$


COLOURS IN THIN FILMS

When white light is made incident on a thin film (like oil film on the surface of water or a soap bubble) Then interference takes place between the waves reflected from its two surfaces and waves refracted through it. The intensity becomes maximum and minimum as a result of interference and colours are seen.

(i) The source of light must be an extended source

(ii) The colours obtained in reflected and transmitted light are mutually complementary.

(iii) The colours obtains in thin films are due to interference whereas those obtained in prism are due to dispersion.

INTERFERENCE DUE TO THIN FILMS

Consider a thin transparent film of thickness t and refractive index μ. Let a ray of light AB incident on the film at B. At B, a part of light is reflected along BR_1, and a part of light refracted along BC. At C a part of light is reflected along CD and a part of light transmitted along CT_1. At D, a part of light is refracted along DR_2 and a part of light is reflected along DE. Thus interference in this film takes place due to reflected light in between BR_1 and DR_2 also in transmitted light in between CT_1 and ET_2.

E
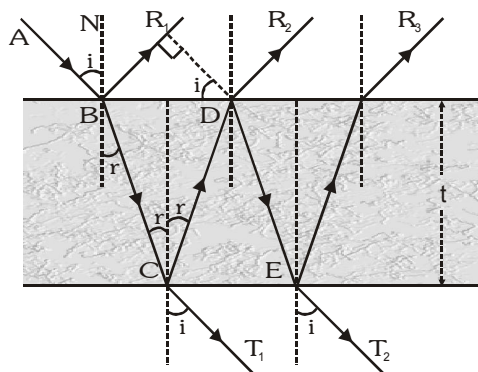
• **Reflected System**

The path difference between BR_1 and DR_2 is $x = 2\mu t \cos r$ due to reflection from the surface of denser medium involves an additional phase difference of π or path difference $\lambda/2$. Therefore the exact path difference between BR_1 and DR_2 is. $\Rightarrow x' = 2\mu t \cos r - \lambda/2$ maximum or constructive Interference occurs when path difference between the light waves is $n\lambda$ .2 $\mu t \cos r - \lambda/2 = n\lambda \Rightarrow 2\mu t \cos r = n\lambda + \lambda/2$

So the film will appear bright if $2\mu t \cos r = (2n + 1) \lambda/2$ (n = 0, 1, 2, 3 .....)

• **For minima or destructive interference :**

When path difference is odd multiple of $\dfrac{\lambda}{2} \Rightarrow 2\mu t \cos r - \dfrac{\lambda}{2} = (2n - 1)\dfrac{\lambda}{2}$

So the film will appear dark if $2\mu t \cos r = n\lambda$

• **For transmitted system**

Since No additional path difference between transmitted rays $C T_1$ and $E T_2$.

So the net path difference between them is $x = 2\mu t \cos r$

For maxima $2\mu t \cos r = n\lambda$, n = 0, 1, 2.............

Minima $2\mu t \cos r = (2n +1) \dfrac{\lambda}{2}$, n = 0, 1, 2.............s

USES OF INTERFERENCE EFFECT

Thin layer of oil on water and soap bubbles show different colours due to interference of waves reflected from two surfaces of their films. Similarly when a lens of large radius of curvature is placed on a plane glass plate, an air film exist between the plate and the lens. If sodium light is put on this film, concentric bright and dark interference rings are formed. These rings are called as Newton's rings.

Uses :

• Used to determine the wavelength of light precisely.

• Used to determine refractive index or thickness of transparent sheet.

• Used to test the flatness of plane surfaces. These surfaces are knows as optically plane surfaces.

• Used to calibrate meters in terms of wavelength of light.

• Used to design optical filter which allows a narrow band of wavelength to pass through it.

• Used in holography to produce 3-D images.

Example

Light of wavelength 6000Å is incident on a thin glass plate of refractive index 1.5 such that angle of refraction into the plate is 60°. Calculate the smallest thickness of plate which will make it appear dark by reflection.

Solution

$$2\mu t \cos r = n\lambda \Rightarrow t = \frac{n\lambda}{2\mu\cos r} = \frac{1\times 6\times 10^{-7}}{2\times 1.5\times \cos 60} = \frac{6\times 10^{-7}}{1.5} = 4\times 10^{-7}\, m$$

Example

Light is incident on a glass plate ($\mu = 1.5$) such that angle of refraction is 60°. Dark band is observed corresponding to the wavelength of 6000Å. If the thickness of glass plate is 1.2×10^{-3} mm. calculate the order of the interference band.

Solution

$\mu = 1.5$, $r = 60°$, $\lambda = 6000\text{Å} = 6\times 10^{-7}\, m \Rightarrow t = 1.2\times 10^{-3} = 1.2\times 10^{-6}\, m$

For dark band in the reflected light $2\,\mu t \cos r = n\lambda$

$$n = \frac{2\mu t \cos r}{\lambda} = \frac{2\times 1.5\times 1.2\times 10^{-6}\times \cos 60°}{6\times 10^{-7}} = \frac{2\times 1.5\times 1.2\times 10^{-6}\times \dfrac{1}{2}}{6\times 10^{-7}} = 3$$

Thus third dark band is observed.

SOME WORKED OUT EXAMPLES

Example#1

State two conditions to obtain sustained interference of light. In Young's double slit experiment, using light of wavelength 400 nm, interference fringes of width 'X' are obtained. The wavelength of light is increased to 600 nm and the separation between the slits is halved. If one wants the observed fringe width on the screen to be the same in the two cases, find the ratio of the distance between the screen and the plane of the slits in the two arrangements.

Sol. Conditions for sustained interference of light

(i) Sources should be coherent.　(ii)　There should be point sources

$\because$ fringe width $\beta = \dfrac{\lambda D}{d}$ Here, $\beta_1 = \dfrac{\lambda_1 D_1}{d_1}$ and $\beta_2 = \dfrac{\lambda_2 D_2}{d_2}$

As $\beta_1 = \beta_2 \Rightarrow \dfrac{\lambda_1 D_1}{d_1} = \dfrac{\lambda_2 D_2}{d_2} \Rightarrow \dfrac{D_1}{D_2} = \dfrac{\lambda_2 d_1}{\lambda_1 d_2} = \dfrac{600}{400} \times \dfrac{1}{1/2} = \dfrac{6}{2} = \dfrac{3}{1}$
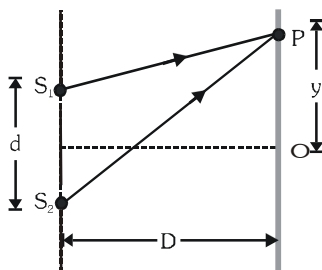
Example#2

Young's double slit experiment is carried out using microwaves of wavelength $\lambda = 3$ cm. Distance in between plane of slits and the screen is $D = 100$ cm. and distance in between the slits is 5 cm. Find

(a) the number of maximas and　(b) their positions on the screen

Sol. (a) The maximum path difference that can be produced = distance between the sources or 5 cm. Thus, in this case we can have only three maximas, one central maxima and two on its either side for a path difference of λ or 3 cm.

(b) For maximum intensity at P, $S_2P - S_1P = \lambda \Rightarrow \sqrt{(y + d/2)^2 + D^2} - \sqrt{(y - d/2)^2 + D^2} = \lambda$

substiuting $d = 5$ cm, $D = 100$ cm and $\lambda = 3$cm we get $y = \pm 75$ cm

Thus, the three maximas will be at $y = 0$ and $y = \pm 75$ cm

Example#3

A beam of light consisting of two wavelengths 6500 Å and 5200 Å is used to obtain interference fringes in a young's double slit experiment. The distance between the slits is 2 mm and the distance between the plane of the slits and screen is 120 cm.

(a) Find the distance of the third bright fringe on the screen from the central maxima for the wavelength 6500 Å.

(b) What is the least distance from the central maxima where the bright fringes due to both the wave-lengths coincide ?

Sol. (a) Distance of third bright fringe from centre of screen

$$x_3 = \frac{nD\lambda}{d} = \frac{3 \times 120 \times 10^{-2} \times 6500 \times 10^{-10}}{2 \times 10^{-3}} = 1.17 \quad 10^{-3} \text{ m} = 1.17 \text{ mm}$$

(b) When bright fringes coincide to each other then $n_1\lambda_1 = n_2\lambda_2 \Rightarrow \dfrac{n_1}{n_2} = \dfrac{\lambda_2}{\lambda_1} = \dfrac{5200\text{Å}}{6500\text{Å}} = \dfrac{4}{5}$

for minimum value of n_1 & n_2 $\quad n_1 = 4, \quad n_2 = 5$

$$\text{So} \quad x = \frac{n_1\lambda_1 D}{d} = \frac{4 \times 6500 \times 10^{-10} \times 120 \times 10^{-2}}{2 \times 10^{-3}} = 0.156 \quad 10^{-2} \text{ m} = 0.156 \text{ cm}$$

Example#4

An electromagnetic wave of wavelength λ_0 (in vacuum) passes from P towards Q crossing three different media of refractive index μ, 2μ and 3μ respectively as shown in figure. ϕ_P and ϕ_Q be the phase of the wave at points P and Q. Find the phase difference $\phi_Q - \phi_P$. [Take : $\mu=1$]
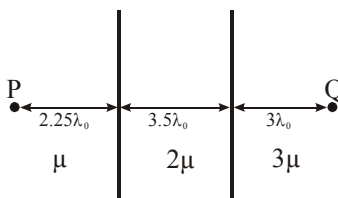
(A) 0   (B) $\dfrac{\pi}{4}$ (C) $\dfrac{\pi}{2}$ (D) π

Solution   **Ans. (C)**

Optical path difference between (OPD) P & Q

(O.P.D.) $= 2.25 \lambda_0 \quad 1 + (3.5 \lambda_0) \quad 2 + 3\lambda_0 \quad 3 = 18.25 \lambda_0$ and phase difference $\Delta\phi = \dfrac{2\pi}{\lambda_0} \times \Delta x = \dfrac{\pi}{2}$

Example#5

Two slits separated by a distance of 1 mm are illuminated with red light of wavelength $6.5 \ 10^{-7}$ m. The interference fringes are observed on a screen placed 1m from the slits. The distance between the third dark fringe and the fifth bright fringe is equal to

(A) 0.65 mm   (B) 1.625 mm   (C) 3.25 mm   (D) 0.975 mm
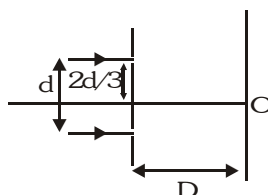
Solution   **Ans. (B)**

Distance between third dark fringe and the fifth bright fringe

$$= \ 2.5\beta = 2.5\frac{\lambda D}{d} = 2.5\frac{6.5 \times 10^{-7} \times 1}{10^{-3}} = 1.625 \text{ mm}$$

Example#6

In the figure shown if a parallel beam of white light is incident on the plane of the slits then the distance of the only white spot on the screen from O is :[assume d << D , λ << d]

(A) 0   (B) d/2   (C) d/3   (D) d/6

E

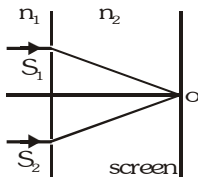**Solution**   Ans. (D)

White spot will be at the symmetrical point w.r.t. slits . Its distance from O will be ,(2d/3) − (d/2) = d/6 .

Example#7

In a Young's double slit experiment the slits S_1 & S_2 are illuminated by a parallel beam of light of wavelength 4000 Å, from the medium of refractive index n_1 = 1.2. A thin film of thickness 1.2µm and refractive index n = 1.5 is placed infront of S_1 perpendicular to path of light. The refractive index of medium between plane of slits & screen is n_2 = 1.4. If the light coming from the film and S_1 & S_2 have equal intensities I then intensity at geometrical centre of the screen O is

(A) 0   (B) 2I   (C) 4I   (D) None of these

Solution   Ans. (B)

Path difference at O : $(\mu_{rel} - 1)\, t = \left(\dfrac{n}{n_2} - 1\right) t$

∴ Phase difference at O: $t\left(\dfrac{n}{n_2} - 1\right)\dfrac{2\pi}{\lambda_2}$ where $n_1\lambda_1 = n_2\,\lambda_2$

⇒ Phase difference$= \dfrac{\pi}{2}$ ⇒ Resultant intensity = 2I

Example#8

In a YDSE experiment two slits S_1 and S_2 have separation of d = 2 mm. The distance of the screen is D = $\dfrac{8}{5}$ 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 monochromatic light is 500 nm. The number of maximas observed on the screen at point P as the source moves towards S_2 is
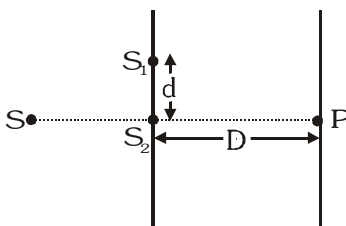
(A) 4001   (B) 3999   (C) 3998   (D) 4000

Solution   Ans. (D)

$$S_1P - S_2P = \frac{d^2}{2D} = \frac{2\times10^{-3}\times 2\times 0^{-3}}{2\times\dfrac{8}{5}} = \frac{5}{2}\lambda \quad (\lambda = 500\,nm)$$

So when S is at ∞ there is I^{st} minima and when S is at S_2 there is last minima because d/λ=4000
So the number of minima's will be 4001 and number of maxima's will be 4000.

Example#9

Consider the optical system shown in figure. The point source of light S is having wavelength equals to λ. The light is reaching screen only after reflection. For point P to be 2nd maxima, the value of λ would be (D>>d and d>>λ)
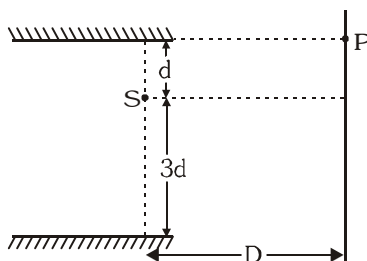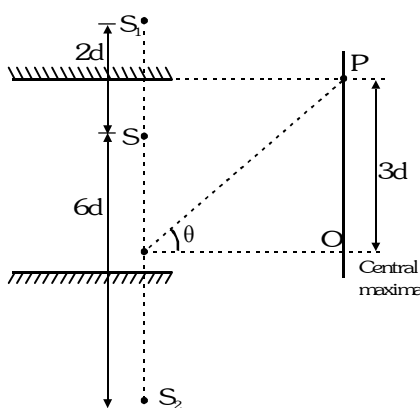

(A) $\dfrac{12d^2}{D}$ 　　　　(B) $\dfrac{6d^2}{D}$ 　　　　(C) $\dfrac{3d^2}{D}$ 　　　　(D) $\dfrac{24d^2}{D}$
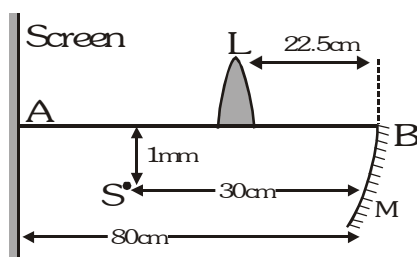
Solution 　　　　　　　　　　　　　　　　　　　　　　　　　　　　　　　　　　　**Ans. (A)**

At P, $\Delta x = \dfrac{(8d)\times 3d}{D}$; For 2nd maxima, $\Delta x = 2\lambda \Rightarrow \dfrac{24d^2}{D} = 2\lambda \Rightarrow \lambda = \dfrac{12d^2}{D}$

Example#10 to 12

In the figure shown, S is a point monochromatic light source of frequency 6×10^{14} Hz. M is a concave mirror of radius of curvature 20 cm and L is a thin converging lens of focal length 3.75 cm. AB is the principal axis of M and L.

Light reflected from the mirror and refracted from the lens in succession reaches the screen. An interference pattern is obtained on the screen by this arrangement.

10. Distance between two coherent sources which makes interference pattern on the screen is-

(A) 1 mm 　　　　(B) 0.5 mm 　　　　(C) 1.5 mm 　　　　(D) 0.25 mm

11. Fringe width is-

(A) 1mm 　　　　(B) 0.5 mm 　　　　(C) 1.5 mm 　　　　(D) 0.25 mm

12. If the lens is replaced by another converging lens of focal length $\dfrac{10}{3}$ cm and the lens is shifted towards right by 2.5 cm then-

(A) Fringe width remains same   (B) Intensity of pattern will remain same

(C) Fringe width will change   (D) No interference pattern will form.

Solution

10. Ans. (B)

Wave length of light $\lambda = \dfrac{c}{f} = 5 \times 10^{-7}\,m$

Image formed by M : $\dfrac{1}{v} + \dfrac{1}{-30} = \dfrac{1}{-10} \Rightarrow v = -15$ cm also M $= -\dfrac{v}{u} = -\dfrac{-15}{-30} = -\dfrac{1}{2}$.

This will be located at 15 cm left of M and 0.5 mm above the line AB.

This will act as an object for the lens L.

Now for the lens u = –7.5cm and m $= \dfrac{v}{u} = \dfrac{7.5}{-7.5} = -1$

So it will be at 7.5 cm to the left of L and 0.5 mm below line AB. See the ray diagram. Second image I_2 and source S will act as two slits (as in YDSE) to produce the interference pattern . Distance between them $=$ 0.5 mm $(= d)$
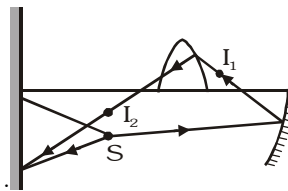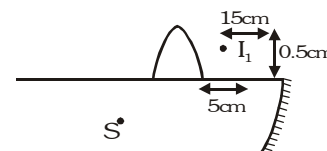
11. Ans. (B)

$\beta = \dfrac{5 \times 10^{-7} \times 50 \times 10^{-2}}{0.5 \times 10^{-3}} = 5 \times 10^{-4}$ m $=$ 0.5 mm

12. Ans. (D)

Image formed by the combination is I_2 at

$\dfrac{1}{v} - \dfrac{1}{-5} = \dfrac{3}{10} \Rightarrow v = 10$ cm . It will coincide with S●,

so no interference pattern on the screen .

Example#13

Statement–1: In Young's double slit experiment the two slits are at distance d apart. Interference pattern is observed on a screen at distance D from the slits. At a point on the screen when it is directly opposite to one of the slits, a dark fringe is observed. Then, the wavelength of wave is proportional to square of distance of two slits.

and

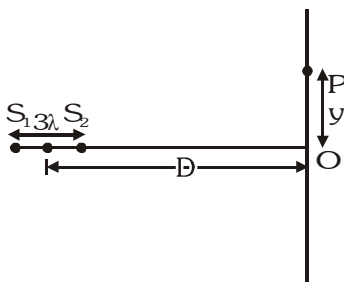**Statement–2 :** In Young's double slit experiment, for identical slits, the intensity of a dark fringe is zero.

(A) Statement–1 is True, Statement–2 is True ; Statement–2 is a correct explanation for Statement–1

(B) Statement–1 is True, Statement–2 is True ; Statement–2 is not a correct explanation for Statement–1

(C) Statement–1 is True, Statement–2 is False.

(D) Statement–1 is False, Statement–2 is True.

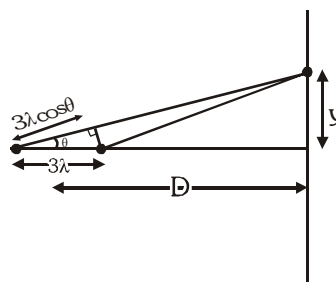**Solution**   **Ans. (B)**

Example#14

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 $\dfrac{\sqrt{m}\,D}{n}$. Determine the value of m + n, if m and n are coprime numbers.

Solution   **Ans. (7)**

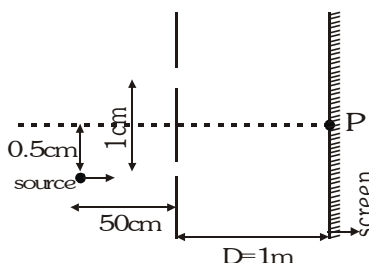Path difference $= 3\lambda \cos\theta = 2\lambda \Rightarrow \cos\theta = \dfrac{2}{3}$

$y = D\tan\theta = \dfrac{D\sqrt{5}}{2} \Rightarrow m + n = 5 + 2 = 7$

Example#15

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=1 mm per second towards the screen, then the instantaneous velocity of central maxima is given as $\alpha \times 10^{-\beta}$ cm/s upward in scientific notation. Find the value of $\alpha+\beta$.
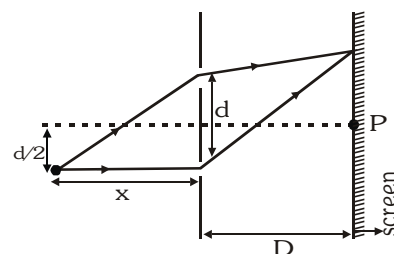

Solution   **Ans. 5**

The central maxima $\dfrac{dy}{D} = \sqrt{d^2 + x^2} - x = x\left[1 + \dfrac{d^2}{2x^2}\right] - x = \dfrac{d^2}{2x}$

$y = \dfrac{Dd}{2x} \Rightarrow \dfrac{dy}{dt} = -\dfrac{Dd}{2x^2}\left(\dfrac{dx}{dt}\right) = \left(\dfrac{1 \times 0.01}{2 \times 0.5 \times 0.5}\right) \times (0.001) = 0.02\,\text{mm}/\text{s}$

$\Rightarrow y = 2 \times 10^{-3}$ cm/s $\Rightarrow \alpha + \beta = 5$

E

<u>Select the correct alternative (only one correct answer)</u>

1. Which of the following phenomenon can not be explained by the Huygen's theory-
   (A) Refraction   (B) Reflection   (C) Diffraction   (D) Formation of spectrum

2. Huygen's principle is applicable to-
   (A) Only light waves   (B) Only sound waves
   (C) Only mechanical waves   (D) For all the above waves

3. According to huygen's theory of secondary waves, following can be explained-
   (A) Propagation of light in medium   (B) Reflection of light
   (C) Refraction of light   (D) All of the above

4. Huygen's theory of secondary waves can be used to find-
   (A) Velocity of light   (B) The wavelength of light
   (C) Wave front geometrically   (D) Magnifying power of microscope

5. The main drawback of huygen's theory was-
   (A) Failure in explanation of rectilinear propagation of lignt
   (B) Failure of explain the spectrum of white light
   (C) Failure to explain the formation of newton's rings
   (D) A failure of experimental verification of ether medium

6. Light has a wave nature, because-
   (A) the light travel in a straight line
   (B) Light exhibts phenomenon of reflection and refraction
   (C) Light exhibits phenomenon interference
   (D) Light exhibits phenomenon of photo electric effect

7. The colour are characterized by which of following character of light–
   (A) Frequency   (B) Amplitude   (C) Wavelength   (D) Velocity

8. Two coherent sources of intensities I_1 and I_2 produce an interference pattern. The maximum intensity in the interference pattern will be :–

   (A) $I_1 + I_2$ (B) $I_1^2 + I_2^2$ (C) $(I_1 + I_2)^2$ (D) $(\sqrt{I_1} + \sqrt{I_2})^2$

9. Two wave are represented by the equations $y_1 = a \sin \omega t$ and $y_2 = a \cos \omega t$. The first wave :–

   (A) leads the second by π (B) lags the seconds by π (C) leads the second by $\dfrac{\pi}{2}$ (D) lags the seconds by $\dfrac{\pi}{2}$

10. The resultant amplitude of a vibrating particle by the superposition of the two waves

    $y_1 = a \sin\left[\omega t + \dfrac{\pi}{3}\right]$ and $y_2 = a \sin \omega t$ is :–

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

11. The energy in the phenomenon of interference :–
    (A) is conserved, gets redistributed   (B) is equal at every point
    (C) is destroyed in regions of dark fringes   (D) is created at the place of bright fringes

12. The phase difference corresponding to path difference of x is :–

    (A) $\dfrac{2\pi x}{\lambda}$ (B) $\dfrac{2\pi\lambda}{x}$ (C) $\dfrac{\pi x}{\lambda}$ (D) $\dfrac{\pi\lambda}{x}$

13. The resultant amplitude in interference with two coherent sources depends upon :–
(A) only amplitude
(B) only phase difference
(C) on both the previous option
(D) none of the above

14. Phenomenon of interference is observed :–
(A) only for light waves
(B) only for sound waves
(C) for both sound and light waves
(D) none of above

15. Two coherent sources must have the same :–
(A) amplitude
(B) phase difference
(C) frequency
(D) both (B) and (C)

16. For the sustained interference of light, the necessary condition is that the two sources should :–
(A) have constant phase difference
(B) be narrow
(C) be close to each other
(D) of same amplitude

17. If the ratio of the intensity of two coherent sources is 4 then the visibility $[(I_{max} - I_{min})/(I_{max} + I_{min})]$ of the fringes is
(A) 4
(B) 4/5
(C) 3/5
(D) 9

18. Two monochromatic and coherent point sources of light are placed at a certain distance from each other in the horizontal plane. The locus of all those points in the horizontal plane which have constructive interference will be–
(A) A hyperbola
(B) Family of hyperbolas
(C) Family of straight lines
(D) Family of parabolas

19. If the distance between the first maxima and fifth minima of a double slit pattern is 7 mm and the slits are separated by 0.15 mm with the screen 50 cm from the slits, then wavelength of the light used is
(A) 600 nm
(B) 525 nm
(C) 467 nm
(D) 420 nm

20. In Young's double slit experiment, the separation between the slits is halved and the distance between the slits and the screen is doubled. The fringe width is :–
(A) unchanged
(B) halved
(C) doubled
(D) quadrupled

21. In Young's double slit experiment using sodium light ($\lambda = 5898$Å), 92 fringes are seen. If given colour ($\lambda = 5461$Å) is used, how many fringes will be seen
(A) 62
(B) 67
(C) 85
(D) 99

22. In Young's experiment, one slit is covered with a blue filter and the other (slit) with a yellow filter. Then the interference pattern :–
(A) will be blue
(B) will be yellow
(C) will be green
(D) will not be formed

23. In Young's double slit experiment, a mica sheet of thickness t and refractive index μ is introduced in the path of ray from the first source S_1. By how much distance the fringe pattern will be displaced

(A) $\dfrac{d}{D}(\mu - 1)t$
(B) $\dfrac{D}{d}(\mu - 1)t$
(C) $\dfrac{d}{(\mu - 1)D}$
(D) $\dfrac{D}{d}(\mu - 1)$

24. In Young's double slit experiment, if monochromatic light is replaced by white light :–
(A) all bright fringes become white
(B) all bright fringes have colours between violet and red
(C) only the central fringe is white, all other fringes are coloured
(D) no fringes are observed

25. In the young's double slit experiment the central maxima is observed to be I_0. If one of the slits is covered, then intensity at the central maxima will become :–

(A) $\dfrac{I_0}{2}$
(B) $\dfrac{I_0}{\sqrt{2}}$
(C) $\dfrac{I_0}{4}$
(D) I_0

26. In Young's double slit experiment, one of the slits is so painted that intensity of light emitted from it is half of that of the light emitted from other slit. Then
(A) fringe system will disappear
(B) bright fringes will become brighter and dark fringes will be darker
(C) both bright and dark fringes will become darker
(D) dark fringes will become less dark and bright fringes will become less bright.

27. In YDSE how many maxima can be obtained on the screen if wavelength of light used is 200 nm and d = 700 nm :
(A) 12   (B) 7   (C) 18   (D) None of these

28. In YDSE, the source placed symmetrically with respect to the slit is now moved parallel to the plane of the slits it is closer to the upper slit, as shown. Then ,
(A) the fringe width will increase and fringe pattern will shift down.
(B) the fringe width will remain same but fringe pattern will shift up.
(C) the fringe width will decrease and fringe pattern will shift down.
(D) the fringe width will remain same but fringe pattern will shift down.
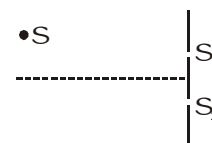
29. In a YDSE experiment if a slab whose refractive index can be varied is placed in front of one of the slits then the variation of resultant intensity at mid–point of screen with 'μ' will be best represented by ($\mu \geq 1$). [Assume slits of equal width and there is no absorption by slab]

(A)   (B)   (C)   (D)
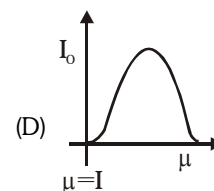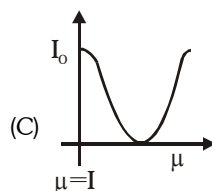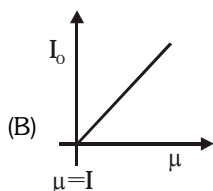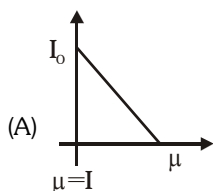
30. In a double slit experiment, instead of taking slits of equal widths, one slit is made twice as wide as the other. Then in the interference pattern.
(A) the intensifies of both the maxima and minima increase.
(B) the intensity of the maxima increases and the minima has zero intensity.
(C) the intensity of the maxima decreases and that of minima increases
(D) the intensity of the maxima decreases and the minima has zero intensity.

31. A ray of light is incident on a thin film. As shown in figure M, N are two reflected rays and P, Q are two transmitted rays, Rays N and Q undergo a phase change of π. Correct ordering of the refracting indices is :
(A) $n_2 > n_3 > n_1$ (B) $n_3 > n_2 > n_1$
(C) $n_3 > n_1 > n_2$ (D) none of these, the specified changes can not occur
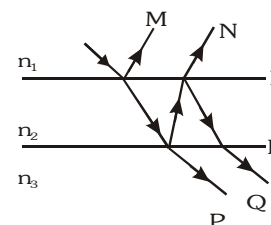
32. Let S_1 and S_2 be the two slits in Young's double slit experiment. If central maxima is observed at P and angle $\angle S_1 P S_2 = \theta$, then the fringe width for the light of wavelength λ will be. (Assume θ to be a small angle)
(A) λ/θ (B) $\lambda\theta$ (C) $2\lambda/\theta$ (D) $\lambda/2\theta$

33. When light is refracted into a denser medium-
(A) Its wavelength and frequency both increase.
(B) Its wavelength increases but frequency remains unchanged.
(C) Its wavelength decreases but frequency remains unchanged.
(D) its wavelength and frequency both decrease.

34. Two point source separated by d = 5 μm emit light of wavelength λ=2 μm in phase. A circular wire of radius 20 μm is placed around the source as shown in figure.
(A) Points A and B are dark and points C and D are bright.
(B) Points A and B are bright and point C and D are dark.
(C) Points A and C are dark and points B and D are bright.
(D) Points A and C are bright and points B and D are dark.
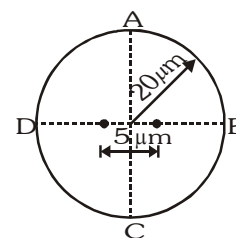
35. Two coherent narrow slits emitting light of wavelength λ in the same phase are placed parallel to each other at a small separation of 3λ. The light is collected on a screen S which is placed at a distance D ($>>\lambda$) from the slits. The smallest distance x such that the P is a maxima.
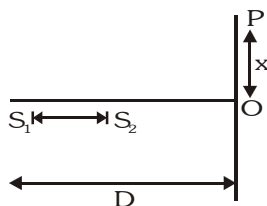
(A) $\sqrt{3D}$ (B) $\sqrt{8}D$ (C) $\sqrt{5}D$ (D) $\sqrt{5}\dfrac{D}{2}$

36. Minimum thickness of a mica sheet having $\mu = \dfrac{3}{2}$ which should be placed in front of one of the slits in YDSE is required to reduce the intensity at the centre of screen to half of maximum intensity is-

(A) $\lambda/4$ (B) $\lambda/8$ (C) $\lambda/2$ (D) $\lambda/3$

37. In the YDSE shown the two slits are covered with thin sheets having thickness t & 2t and refractive index 2μ and μ. Find the position (y) of central maxima
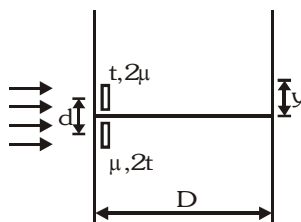
(A) zero   (B) $\dfrac{tD}{d}$ (C) $-\dfrac{tD}{d}$ (D) None of these

38 In a YDSE with two identical slits, when the upper slit is covered with a thin, perfectly transparent sheet of mica, the intensity at the centre of screen reduces to 75% of the initial value. Second minima is observed to be above this point and third maxima below it. Which of the following can not be a possible value of phase difference caused by the mica sheet

(A) $\dfrac{\pi}{3}$ (B) $\dfrac{13\pi}{3}$ (C) $\dfrac{17\pi}{3}$ (D) $\dfrac{11\pi}{3}$

| CHECK YOUR GRASP									ANSWER KEY								EXERCISE –1		
Que.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Ans.	D	D	D	C	D	C	A	D	D	D	A	A	C	C	D	A	B	B	A	D
Que.	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38		
Ans.	D	D	B	C	C	D	B	D	C	A	B	A	C	D	B	C	B	A		

E

Select the correct alternatives (one or more than one correct answers)

1. As shown in arrangement waves with identical wavelengths 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 wavelengths in length L is N_2 for Ray 2 and N_1 for Ray 1. In the following table, values of N_1 and N_2 are given for all four situations, The order of the situations according to the intensity of the light at the common point in descending order is :

| Situations	1	2	3	4
N_1	2.25	1.80	3.00	3.25
N_2	2.75	2.80	3.25	4.00
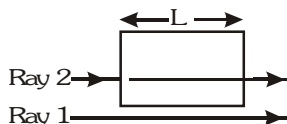
(A) $I_3 = I_4 > I_2 > I_1$ (B) $I_1 > I_3 = I_4 > I_2$ (C) $I_1 > I_2 > I_3 > I_4$ (D) $I_2 > I_3 = I_4 > I_1$

2. The path difference between two interfering waves at a point on the screen is $\lambda/6$. The ratio of intensity at this point and that at the central bright fringe will be : (Assume that intensity due to each slit is same)
    (A) 0.853   (B) 8.53   (C) 0.75   (D) 7.5

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 λ_1. A transparent slab of thickness 't' and refractive index n_3 is put in front 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 :
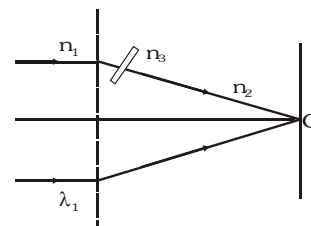
    (A) $\dfrac{2\pi}{n_1\lambda_1}$ $(n_3 - n_2)$ t   (B) $\dfrac{2\pi}{\lambda_1}$ $(n_3 - n_2)$ t   (C) $\dfrac{2\pi n_1}{n_2\lambda_1}\left(\dfrac{n_3}{n_2}-1\right)t$ (D) $\dfrac{2\pi n_1}{\lambda_1}$ $(n_3 - n_2)$ t

4. 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 : [assume d << D, λ << d]
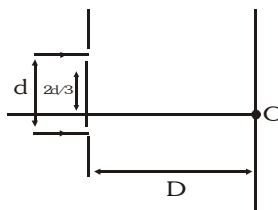
    (A) 0   (B) d/2   (C) d/3   (D) d/6

5. In the figure shown, a parallel beam of light is incident on the plane of the slits of 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:
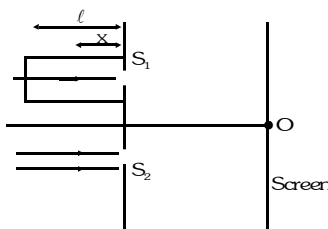
    (A) $\dfrac{\lambda}{\ell}$ (B) $\dfrac{\lambda}{\ell^2}$ (C) $\dfrac{\ell^2}{\lambda}$ (D) none of these

6. M_1 and M_2 are plane mirrors and kept parallel to each other. At point O there will be a maxima for wavelength λ. Light from monochromatic source S of wavelength λ is not reaching directly on the screen. Then λ is : [D >> d >> λ]

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

(B) $\dfrac{3d^2}{2D}$

(C) $\dfrac{d^2}{D}$

(D) $\dfrac{2d^2}{D}$
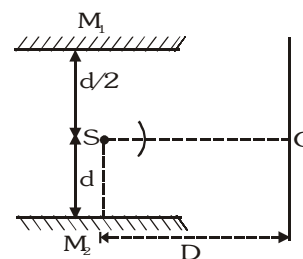
7. If the first minima in a Young's slit experiment occurs directly in front of one of the slits, (distance between slit & screen D = 12 cm and distance between slits d = 5 cm) then the wavelength of the radiation used can be :

(A) 2 cm   (B) 4 cm   (C) $\dfrac{2}{3}$ cm   (D) $\dfrac{4}{3}$ cm

8. 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) $\lambda/2$ (C) 2λ (D) $3\lambda/2$

9. 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 becomes more bright
(D) The fringe width will remain unchanged

10. White light is used to illuminate the two slits in a Young's double slit experiment. The separation between the slits is b and the screen is at a distance d (>> b) from the slits. At a point on the screen directly in front of one of the slits, certain wavelengths are missing. Some of these missing wavelengths are :
(A) $\lambda = b^2/d$ (B) $\lambda = 2b^2/d$ (C) $\lambda = b^2/3d$ (D) $\lambda = 2b^2/3d$

11. 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 10^6 Hz. The sources are synchronized to have zero phase difference. The slits are separated by a distance d = 150.0m. The intensity $I(\theta)$ is measured as a function of θ, where θ is defined as shown. If I_0 is the maximum intensity, then $I(\theta)$ for $0 \leq \theta \leq 90$ is given by :
(A) $I(\theta) = I_0/2$ for $\theta = 30$ (B) $I(\theta) = I_0/4$ for $\theta = 90$
(C) $I(\theta) = I_0$ for $\theta = 0$ (D) $I(\theta)$ is constant for all values of θ
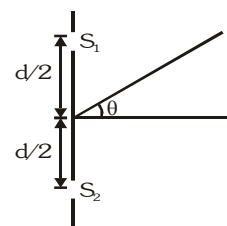
12. Figure shows plane waves refracted from air to water using Huygen's principle a,b,c,d,e are lengths on the diagram. The refractive index of water w.r.t air is the ratio.
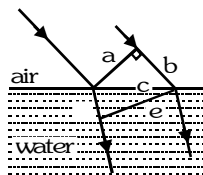
(A) a/e   (B) b/e   (C) b/d   (D) d/b

13. A monochromatic light source of wavelength λ is placed at S. Three slits S_1, S_2 and S_3 are equidistant from the source S and the point P on the screen. $S_1P - S_2P = \lambda/6$ and $S_1P - S_3P = 2\lambda/3$. If I be the intensity at P when only one slit is open, the intensity at P when all the three slits are open is–

(A) 3 I   (B) 5 I   (C) 8 I   (D) zero

E
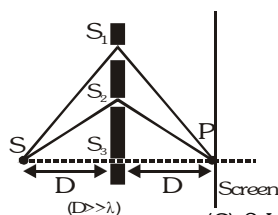
14. In a Young's double slit experiment, green light is incident on the two slits. The interference pattern is observed on a screen. Which of the following changes would cause the observed fringes to be more closely spaced ?
(A) Reducing the separation between the slits
(B) Using blue light instead of green light
(C) Used red light instead of green light
(D) Moving the light source further away from the slits.
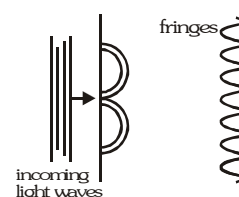
15. Two monochromatic (wavelength = a/5) and coherent sources of electromagnetic waves are placed on the x-axis at the points (2a,0) and (–a,0). A detector moves in a circle of radius R(>>2a) whose centre is at the origin. The number of maximas detected during one circular revolution by the detector are-
(A) 60 (B) 15 (C) 64 (D) None

16. In a Young's Double slit experiment, first maxima is observed at a fixed point P on the screen. Now the screen is continuously moved away from the plane of slits. The ratio of intensity at point P to the intensity at point O (centre of the screen)-
(A) Remains constant
(B) Keeps on decreasing
(C) First decreases and then increases
(D) First decreases and then becomes constant
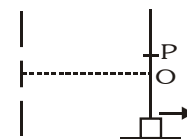
17. To make the central fringe at the centre O, a mica sheet of refractive index 1.5 is introduced. Choose the correct statements (s)-

(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.
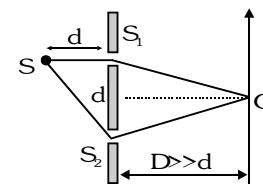
18. A thin slice is cut out of a glass cylinder along a plane parallel to its axis. The slice is placed on a flat glass plate with the curved surface downwards. Monochromatic light is incident normally from the top. The observed interference fringes from the combination do not follow on of the following statements.
(A) The fringes are straight and parallel to the length of the piece.
(B) The line of contact of the cylindrical glass piece and the glass plate appears dark.
(C) The fringe spacing increases as we go outwards.
(D) The fringes are formed due to the interference of light rays reflected from the curved surface of the cylindrical piece and the top surface of the glass plate.

19. A circular planar wire loop is dipped in a soap solution and after taking it out, held with its plane vertical in air. Assuming thickness of film at the very small, as sunlight falls on the soap film, & observer receive reflected light.
(A) The top portion appears dark while the first colour to be observed as one moves down is red.
(B) The top portion appears violet while the first colour to be observed as one moves down in indigo.
(C) The top potion appears dark while the first colour to be observed as one move down in violet.
(D) The top portion appears dark while the first colour to be observed as one move down depends on the refractive index of the soap solution.

20. Soap bubble appears coloured due to the phenomenon of :–
(A) interference (B) diffraction (C) dispersion (D) reflection

21. A parallel coherent beam of light falls on fresnel biprism of refractive index μ and angle α. The fringe width on a screen at a distance D from biprism will be (wavelength = λ)
(A) $\dfrac{\lambda}{2(\mu-1)\alpha}$ (B) $\dfrac{\lambda D}{2(\mu-1)\alpha}$ (C) $\dfrac{D}{2(\mu-1)\alpha}$ (D) None of these

Que.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Ans.	D	C	A	D	B	B	A,C	A,B	A,C,D	A,C	A,C	C	A	B	A	C	A	C	C	A	A

BRAIN TREASURE **ANSWER KEY** EXERCISE –2

# EXERCISE–03   MISCELLANEOUS TYPE QUESTIONS

True/False

1. The intensity of light at a distance r from the axis of a long cylindrical source is inversely proportional to r.

2. Two slits in a Young's double slit experiment are illuminated by two different sodium lamps emitting light of the same wavelength. No interference pattern will be observed on the screen.

3. In a Young's double slit experiment performed with a source of white light, only black and white fringes are observed.

Fill in the blanks

1. A light wave of frequency 5×10^{14} Hz enters a medium of refractive index 1.5. In the medium the velocity of the light wave is ……. and its wavelength is……

2. A monochromatic beam of light of wavelength 6000Å in vacuum enters a medium of refractive index 1.5. In the medium its wavelength is………, its frequency is …….

3. In Young's double–slit experiment, the two slits act as coherent sources of equal amplitude A and of wavelength λ. In another experiment with the same set–up the two slits are sources of equal amplitude A and wavelength λ, but are incoherent. The ratio of the intensity of light at the mid–point of the screen in the first case to that in the second case is ……

Match the column

1. A double slit interference pattern is produced on a screen, as shown in the figure, using monochromatic light of wavelength 500nm. Point P is the location of the central bright fringe, that is produced when light waves arrive in phase without any path difference. A choice of three strips A, B and C of transparent materials with different thicknesses and refractive indices is available, as shown in the table. These are placed over one or both of the slits, singularly or in conjunction, causing the interference pattern to be shifted across the screen from the original pattern. In the column–I, how the strips have been placed, is mentioned whereas in the column–II, order of the fringe at point P on the screen that will be produced due to the placement of the strips(s), is shown. Correctly match both the column.
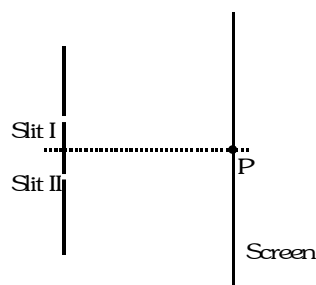
Film	A	B	C
Thickness (in μm)	5	1.5	0.25
Refractive index	1.5	2.5	2

Column I

(A) Only strip B is placed over slit–I

(B) Strip A is placed over slit–I and strip C is placed over slit–II

(C) Strip A is placed over the slit–I and strip B and strip C are placed over the slit–II in conjunction

(D) Strip A and strip C are placed over slit–I (in conjuction) and strip B is placed over Slit–II

Column II

(p) First Bright

(q) Fourth Dark

(r) Fifth Dark

(s) Central Bright

(t) Fifth bright

E

Assertion–Reason

1. **Statement–1 :** If white light is used in YDSE, then the central bright fringe will be white

   and

   Statement–2 : In case of white light used in YDSE, all the wavelengths produce their zero order maxima at the same position

   (A) Statement–1 is True, Statement–2 is True ; Statement–2 is a correct explanation for Statement–1

   (B) Statement–1 is True, Statement–2 is True ; Statement–2 is not a correct explanation for Statement–1

   (C) Statement–1 is True, Statement–2 is False.

   (D) Statement–1 is False, Statement–2 is True.

2. **Statement–1 :** In YDSE, if a thin film is introduced in front of the upper slit, then the fringe pattern shifts in the downward direction.

   and

   Statement–2 : In YDSE if the slit widths are unequal, the minima will be completely dark

   (A) Statement–1 is True, Statement–2 is True ; Statement–2 is a correct explanation for Statement–1

   (B) Statement–1 is True, Statement–2 is True ; Statement–2 is not a correct explanation for Statement–1

   (C) Statement–1 is True, Statement–2 is False.

   (D) Statement–1 is False, Statement–2 is True.

3. **Statement–1:** In YDSE, interference pattern disappears when one of the slits is closed.

   and

   Statement–2 : In YDSE, interference occurs due to super–imposition of light wave from two coherent sources.

   (A) Statement–1 is True, Statement–2 is True ; Statement–2 is a correct explanation for Statement–1

   (B) Statement–1 is True, Statement–2 is True ; Statement–2 is not a correct explanation for Statement–1

   (C) Statement–1 is True, Statement–2 is False.

   (D) Statement–1 is False, Statement–2 is True.

4. **Statement–1 :** In YDSE central maxima means the maxima formed with zero optical path difference. It may be formed anywhere on the screen.

   and

   Statement–2 : In an interference pattern, whatever energy disappears at the minimum, appears at the maximum.

   (A) Statement–1 is True, Statement–2 is True ; Statement–2 is a correct explanation for Statement–1

   (B) Statement–1 is True, Statement–2 is True ; Statement–2 is not a correct explanation for Statement–1

   (C) Statement–1 is True, Statement–2 is False.

   (D) Statement–1 is False, Statement–2 is True.

5. **Statement–1:** The phase difference between any two points on a wave front is zero.

   and

   Statement–2 : Light from the source reaches every point of the wave front at the same time.

   (A) Statement–1 is True, Statement–2 is True ; Statement–2 is a correct explanation for Statement–1

   (B) Statement–1 is True, Statement–2 is True ; Statement–2 is not a correct explanation for Statement–1

   (C) Statement–1 is True, Statement–2 is False.

   (D) Statement–1 is False, Statement–2 is True.

6. **Statement-1 :** As light travels from one medium to another, the frequency of light doesn't change.

and

Statement-2 : Frequency is the characteristic of source.

(A) Statement-1 is True, Statement-2 is True ; Statement-2 is a correct explanation for Statement-1

(B) Statement-1 is True, Statement-2 is True ; Statement-2 is not a correct explanation for Statement-1

(C) Statement-1 is True, Statement-2 is False.

(D) Statement-1 is False, Statement-2 is True.

7. **Statement-1:**No interference pattern is detected when two coherent sources are infinitely close to each other.

and

Statement-2 : The fringe width is inversely proportional to the distance between the two slits.

(A) Statement-1 is True, Statement-2 is True ; Statement-2 is a correct explanation for Statement-1

(B) Statement-1 is True, Statement-2 is True ; Statement-2 is not a correct explanation for Statement-1

(C) Statement-1 is True, Statement-2 is False.

(D) Statement-1 is False, Statement-2 is True.

Comprehension based question

Comprehension#1

The lens governing the behavior of the rays namely rectilinear propagation, laws of reflection and refraction can be summarised in one fundamental law known as Fermat's principle. According to this principle a ray of light travels from one point to another such that the time taken is at a stationary value (maximum or minimum). If c is the velocity of light in a vacuum, the velocity in a medium of refractive index $\mu$ is $\dfrac{c}{\mu}$, hence time taken to travel a distance ℓ is $\dfrac{\mu\ell}{c}$. If the light passes through a number of media, the total time taken is $\left(\dfrac{1}{c}\right)\sum \mu\ell$ or $\dfrac{1}{c}\int \mu d\ell$ if refractive index varies continuously. Now, $\sum \mu\ell$ is the total optical path, so that Fermat's principle states that the path of a ray is such that the optical path in at a stationary value. This principle is obviously in agreement with the fact that the ray are straight lines in a homogenous isotropic medium. It is found that it also agrees with the classical laws of reflection and refraction.

1. If refractive index of a slab varies as $\mu = 1 + x^2$ where x is measured from one end, then optical path length of a slab of thickness 1 m is :

(A) $\dfrac{4}{3}$m (B) $\dfrac{3}{4}$m (C) 1 m (D) None

2. The optical path length followed by ray from point A to B given that laws of refraction are obeyed as shown in figure.
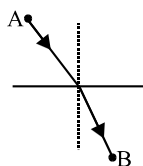
(A) Maximum (B) Minimum (C) Constant (D) None

3. The optical path length followed by ray from point A to B given that laws of reflection are obeyed as shown in figure is


A and B are focii of ellipse
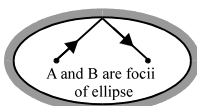
(A) Maximum (B) Minimum (C) Constant (D) None

E

Comprehension#2

Huygen was the first scientist who proposed the idea of wave theory of light. He said that the light propagates in form of wavefronts. A wavefront is an imaginary surface of every point of which waves are in the same phase.

For example the wavefronts for a point source of light is collection of concentric spheres which have centre at the origin. w_1 is a wavefront. w_2 is another wavefront.
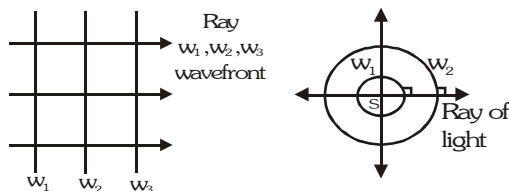
The radius of the wavefront at time 't' is 'ct' in this case where 'c' is the speed of light. The direction of propagation of light is perpendicular to the surface of the wavefront. The wavefronts are plane wavefronts in case of a parallel beam of light.
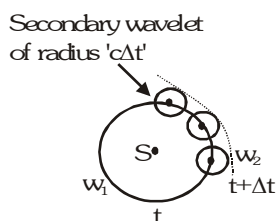

Huygen also said that every point of the wavefront acts as the source of secondary wavelets. The tangent drawn to all secondary wavelets at a time is the new wavefront at that time. The wavelets are to be considered only in the forward direction (i.e. the direction of propagation of light) and not in the reverse direction. If a wavefront w_1 at time t is given, then to draw the wavefront at time t + Δt take some points on the wavefront w_1 and draw spheres of radius 'cΔt'. They are called secondary wavelets.

Draw a surface w_2 which is tangential to all these secondary wavelets. w_2 is the wavefront at time 't + Δt'. Huygen proved the laws of reflection and laws of refraction using concept of wavefronts.

1. A point source of light is placed at origin, in air. The equation of wavefront of the wave at time t, emitted by source at t = 0, is (Take refractive index of air as 1)

(A) $x + y + z = ct$ (B) $x^2 + y^2 + z^2 = t^2$ (C) $xy + yz + zx = c^2t^2$ (D) $x^2 + y^2 + z^2 = c^2 t^2$

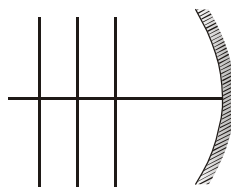2. Spherical wavefronts shown in figure, strike a plane mirror. Reflected wavefront will be as shown in
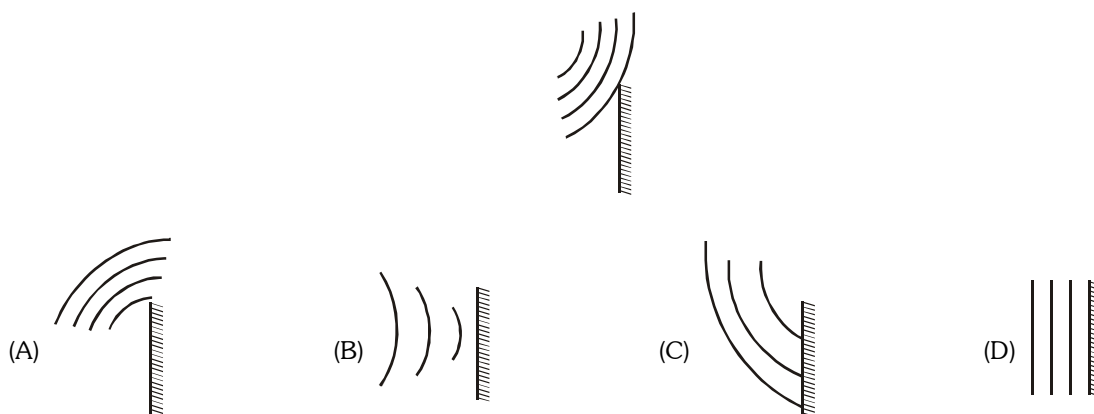
(A)   (B)   (C)   (D)

3. Wavefronts incident on an interface between the media are shown in the figure. The refracted wavefront will be as shown in
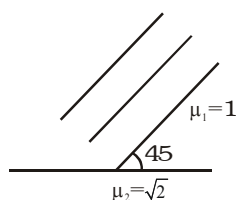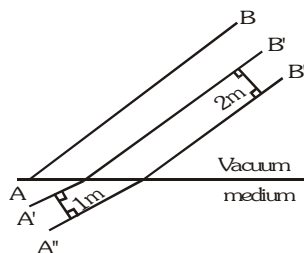

(A) (B) (C) (D)

4. Plane wavefronts are incident on a spherical mirror as shown in the figure. The reflected wavefronts will be

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

5. Certain plane wavefronts are shown in figure. The refractive index of medium is
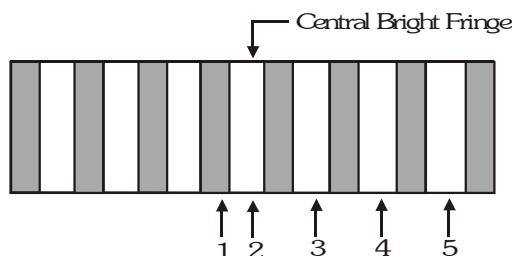

(A) 2   (B) 4   (C) 1.5   (D) Cannot be determined

6. The wavefront of a light beam is given by the equation $x + 2y + 3z = c$, (where c is arbitrary constant) then the angle made by the direction of light with the y–axis is:

(A) $\cos^{-1}\dfrac{1}{\sqrt{14}}$ (B) $\sin^{-1}\dfrac{2}{\sqrt{14}}$ (C) $\cos^{-1}\dfrac{2}{\sqrt{14}}$ (D) $\sin^{-1}\dfrac{3}{\sqrt{14}}$

E

Comprehension#3

The figure shows the interference pattern obtained in a double–slit experiment using light of wavelength 600nm.

1. The third order bright fringe is

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

2. Which fringe results from a phase difference of 4π between the light waves incidenting from two slits?

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

3. Let ΔX_A and ΔX_C represent path differences between waves interfering at 1 and 3 respectively then $(|\Delta X_C| - (|\Delta X_A|)$ is equal to

   (A) 0   (B) 300 mn   (C) 600 nm   (D) 900 nm

Comprehension#4

The figure shows a schematic diagram showing the arrangement of Young's Double Slit experiment
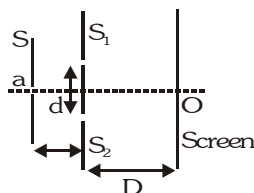
1. Choose the correct statement (s) related to the wavelength of light used.

   (A) Larger the wavelength of light larger the fringe width

   (B) The position of central maxima depends on the wavelength of light used

   (C) If white light is used in YDSE, then the violet colour forms its first maxima closest to the central maxima

   (D) The central maxima of all the wavelength coincide

2. If the distance D is varied, then choose the correct statement (s)

   (A) The angular fringe width does not change   (B) The fringe width changes in direct proportion

   (C) The change in fringe width is same for all wavelengths(D) The position of central maxima remains unchanged

3. If the distance d is varied, then identify the correct statement–

   (A) The angular width does not change   (B) The fringe width changes in inverse proportion

   (C) The positions of all maxima change   (D) The positions of all minima change

Comprehension#5

Thin films, including soap bubbles and oil slicks, show patterns of alternating dark and bright regions resulting from interference among the reflected light waves. If two waves are in phase their crest and troughs will coincide. The interference will be constructive and the amplitude of the resultant wave will be greater than the amplitude of either constituent wave. If the two waves are out of phase, the crests of one wave will coincide with the troughs of the other wave. The interference will be destructive and the amplitude of the resultant wave will be less than that of either constituent wave. At the interface between two transparent media, some light is reflected and some light is refracted.
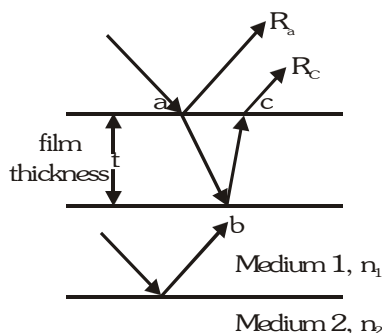
- When incident light, reaches the surface at point a, some of the light is reflected as ray R_a and some is refracted following the path ab to the back of the film.

- At point b some of the light is refracted out of the film and part is reflected back through the film along path bc. At point c some of the light is reflected back into the film and part is refracted out of the film as ray R_c.

  R_a and R_c are parallel. However, R_c has travelled the extra distance within the film of abc. If the angle of incidence is small, then abc is approximately twice the film's thickness. If R_a and R_c are in phase, they will undergo constructive interference and the region ac will be bright. If R_a and R_c are out of phase, they will undergo destructive interference.

- Refraction at an interface never changes the phase of the wave.

- For reflection at the interface between two media 1 and 2, if $n_1 < n_2$ the reflected wave will change phase by π. If $n_1 > n_2$ the reflected wave will not undergo a phase change. For reference $n_{air} = 1.00$.

- If the waves are in phase after reflection at all interfaces, then the effects of path length in the film are:

  Constructive interference occur when : (n = refractive index) $2t = m\lambda/n$ m = 0, 1, 2, 3.........

  Destructive interference occurs when : $2t = (m + 1/2)\lambda/n$ m = 0, 1, 2, 3.........

  If the waves are 180 out of phase after reflection at all interfaces then the effects of path length on the film are :

  Constructive interference occurs when : $2t = (m + 1/2)\lambda/n$ m = 0, 1, 2, 3..........

  Destructive interference occurs when : $2t = m\lambda/n$ m = 0, 1, 2, 3.........

1. A thin film with index of refraction 1.50 coats a glass lens with index of refraction 1.80. What is the minimum thickness of the thin film that will strongly reflect light with wavelength 600 nm ?

(A) 150 nm (B) 200 nm (C) 300 nm (D) 450 nm

2. A thin film with index of refraction 1.33 coats a glass lens with index of refraction 1.50. Which of the following choices is the smallest film thicknesses that will not reflect light with wavelength 640 nm ?

(A) 160 nm (B) 240 nm (C) 360 nm (D) 480 nm

3. A soap film of thickness t is surrounded by air and is illuminated at near normal incidence by monochromatic light with wavelength λ in the film. With respect to the wavelength of the monochromatic light in the film, what film thickness will produce maximum constructive interference in the reflected light

(A) $\dfrac{\lambda}{4\mu}$ (B) $\dfrac{\lambda}{2\mu}$ (C) $\mu\lambda$ (D) $2\mu\lambda$

4. The average human *eye* sees colors with wavelengths between 430 nm to 680 nm. For what visible wavelength will a 350 nm thick n = 1.35 soap film produce maximum destructive interference ?

(A) 560 nm   (B) 473 nm   (C) 610 nm   (D) none of these

5. A 600 nm light is perpendicularly incident on a soap film suspended in air. The film is 1.00 μm thick with n = 1.35. Which statement most accurately describes the interference of the light reflected by the two surfaces of the film ?

(A) The waves are close to destructive interference   (B) The waves are close to constructive interference

(C) The waves show complete destructive interference   (D) The waves show complete constructive interference

MISCELLANEOUS TYPE QUESTION	ANSWER KEY					EXERCISE –3	
● *True / False*	**1.** T	**2.** T	**3.** F				
● *Fill in the Blanks*	**1.** 2×10^8 m/s, 4×10^{-7} m			**2.** 400Å, 5×10^{14} Hz	**3.** 2		
● *Match the Column*	**1.** (A) t (B) r (C) s (D) p						
● *Assertion – Reason*	**1.** A	**2.** E	**3.** B	**4.** B	**5.** A	**6.** A	**7.** A
● *Comprehension Based*							
Comprehension #1:	**1.** A	**2.** B	**3.** C				
Comprehension #2 :	**1.** D	**2.** C	**3.** B	**4.** A	**5.** A	**6.** C	
Comprehension #3 :	**1.** D	**2.** C	**3.** B				
Comprehension #4 :	**1.** A,C,D	**2.** A,B,D	**3.** B,D				
Comprehension #5 :	**1.** B	**2.** C	**3.** A	**4.** B	**5.** D		

EXERCISE–04 [A]   CONCEPTUAL SUBJECTIVE EXERCISE

1. Consider interference between two sources of intensity I and 4I. Find out resultant intensity where phase difference is (i) $\pi/4$ (ii) π (iii) 4π

2. Two coherent sources S_1 and S_2 separated by distance 2λ emit light of wavelength λ in phase as shown in the figure. A circular wire of radius $100\,\lambda$ is placed in such a way that $S_1\,S_2$ lies in its plane and the mid–point of S_1S_2 is at the centre of wire.
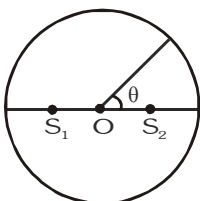

(i) Find the angular positions θ on the wire for which constructive interference takes place. Hence or otherwise find the number of maxima.

(ii) Find the angular positions θ on the wire for which intensity reduces to half of its maximum value.

3. A ray of light of intensity I is incident on a parallel glass–slab at a point A as shown   in figure. It undergoes partial reflection and refraction. At each reflection 20% of incident energy is refracted. The rays AB and A'B' undergo interference. Find the ratio I_{max}/I_{min}.
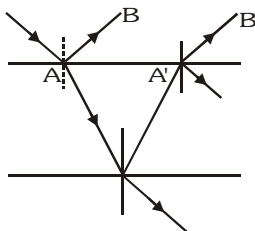
4. In Young's experiment for interference of light the slits 0.2 cm apart are illuminated by yellow light (λ = 5896 A). What would be the fringe width on a screen placed 1m from the plane of slits ? What will be the fringe width if the system is immersed in water. (Refractive index = 4/3)

6. In a double–slit experiment, fringes are produced using light of wavelength 4800 A . One slit is covered by a thin plate of glass of refractive index 1.4 and the other slit by another plate of glass of double thickness and of refractive index 1.7. On doing so, the central bright fringe shifts to a position originally occupied by the fifth bright fringe from the centre. Find the thickness of the glass plates.

7. In a two–slit experiment with monochromatic light, fringes are obtained on a screen placed at some distance from the slits. If the screen is moved by 5×10^{-2} m towards the slits, the change in fringe width is 3×10^{-5}. If the distance between the slits is 10^{-3} m, calculate the wavelength of the light used.

8. Young's double slit experiment is carried out using microwaves of wavelength λ = 3 cm. Distance in between plane of slits and the screen is D = 100 cm and distance in between the slits is 5 cm. Find :(i) The number of maximas and (ii) Their positions on the screen

E

9. A thin glass plate of thickness t and refractive index μ is inserted between screen and one of the slits in a Young's experiment. If the intensity at the centre of the screen is I, what was the intensity at the same point prior to the introduction of the sheet.

10. Light of wavelength 520nm passing through a double slit, produces interference pattern of relative intensity versus deflection angle θ as shown in the figure. Find the separation d between the slits.
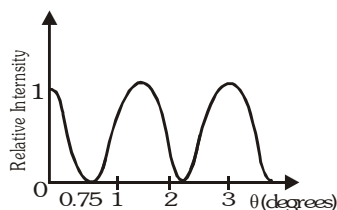
CONCEPTUAL SUBJECTIVE EXERCISE	ANSWER KEY	EXERCISE–4(A)

1. (i) 7.8 I (ii) I (iii) 9I

2. (i) 0 , 60 , 90 , 120 , 180 , 240 , 270 , 300 , 8 (ii) $\cos\theta = \pm\frac{1}{8}, \pm\frac{3}{8}, \pm\frac{5}{8}, \pm\frac{7}{8}$

3. 81 :1   **4.** 0.3 mm, 0.225 mm

6. 2.4 μm and 4.8μm   **7.** 6000Å

8. (i) 3 (ii) y=0 and y = ± 75 cm   **9.** (i) $I_0 = I \cos^2\left[\frac{\pi(\mu-1)t}{\lambda}\right]$

10. 1.98 10^{-2} mm

EXERCISE–04 [B] BRAIN STORMING SUBJECTIVE EXERCISE

1. Two identical monochromatic light sources A & B intensity 10^{-15}W/m produce wavelength of light $4000\sqrt{3}$Å. A glass of thickness 3mm is placed in the path of the ray as shown in figure. The glass has a variable refractive index $n = 1 + \sqrt{x}$ where x (in mm) is distance of plate from left to right. Calculate total intensity at focal point F of the lens.
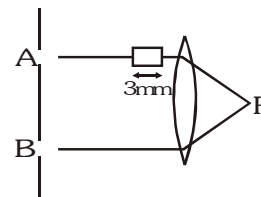
2. Two slits S_1 and S_2 on the x–axis and symmetric with respect to y–axis are illuminated by a parallel monochromatic light beam of wavelength λ. The distance between the slits is d ($>> \lambda$). Point M is the mid point of the line S_1S_2 and this point is considered as the origin. The slits are in horizontal plane. The interference pattern is observed on a horizontal plate (acting as screen) of mass M, which is attached to one end of a vertical spring of spring constant K. The other end of the spring is fixed to ground. At t=0 the plate is at a distance D($>>$d) below the plane of slits and the spring is in its natural length. The plate is left from rest from its initial position. Find the x and y co–ordinates of the nth maxima on the plate as a function of time. Assume that spring is light and plate always remains horizontal.
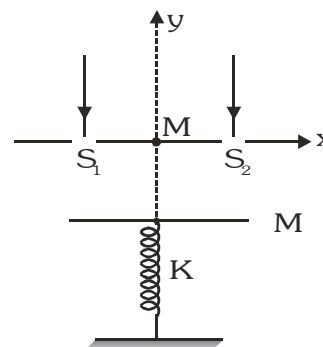
3. In a YDSE a parallel beam of light of wavelength 6000Å is incident on slits at angle of incidence 30. A and B are two thin transparent films each of refractive index 1.5. Thickness of A is 20.4 μm. Light coming through A and B have intensities I and 4I respectively on the screen. Intensity at point O which is symmetric relative to the slits is 3I. The central maxima is above O.
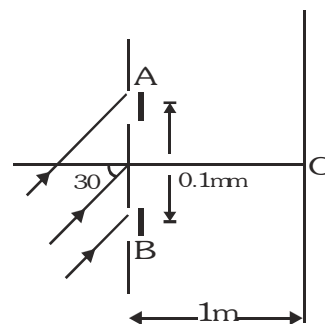
   (i) What is the maximum thickness of B to do so. Assuming thickness of B to be that found in part (i) answer the following parts.

   (ii) Find fringe width, maximum intensity and minimum intensity on screen.

   (iii) Distance of nearest minima from O.

   (iv) Intensity at 5 cm on either side of O.

4. A screen is at a distance D=80 cm from a diaphragm having two narrow slits S_1 and S_2 which are d=2 mm apart. Slit S_1 is covered by a transparent sheet of thickness t_1=2.5 μm and S_2 by another sheet of thickness t_2 = 1.25 μm as shown in figure. Both sheets are made of same material having refractive index μ=1.40.
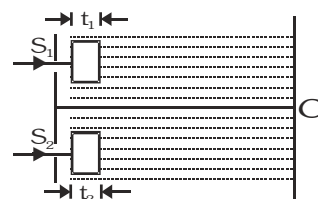
   Water is filled in space between diaphragm and screen. A monochromatic light beam of wavelength λ=5000Å is incident normally on the diaphragm. Assuming intensity of beam to be uniform and slits of equal width, calculate ratio of intensity at C to maximum intensity of interference pattern obtained on the screen, where C is foot of perpendicular bisector of S_1S_2. (Refractive index of water, $\mu_w = \dfrac{4}{3}$)

5. Two plane mirrors, a source S of light, emitting monochromatic rays of wavelength λ and a screen are arranged as shown in figure. If angle θ is very small, calculate fringe width of the interference pattern formed by reflected rays.

E
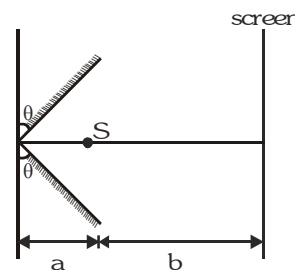
6. In the figure shown S is a monochromatic point source emitting light of wavelength = 500 nm. A thin lens of circular shape and focal length 0.10 m is cut into two identical halves L_1 and L_2 by a plane passing through a diameter. The two halves are placed symmetrically about the central axis SO with a gap of 0.5 mm. The distance along the axis from S to L_1 and L_2 is 0.15 m, while that from L_1 and L_2 to O is 1.30 m.
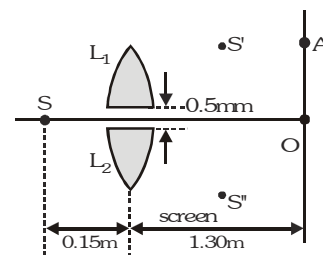

The screen at O is normal to SO. (i) If the third intensity maximum occurs at the point A on the screen, find the distance OA. (ii) If the gap between L_1 and L_2 is reduced from its original value of 0.5 mm, will the distance OA increase decrease or remain the same?

7. Two parallel beams of light P and Q (separation d) containing radiations of wavelengths 4000Å and 5000Å (which are mutually coherent in each wavelength separately) are incident normally on a prism as shown in figure The refractive index of the prism as a function of wavelength is given by the relation, $\mu(\lambda) = 1.20 + \dfrac{b}{\lambda^2}$, where λ is in Å and b is a positive constant.
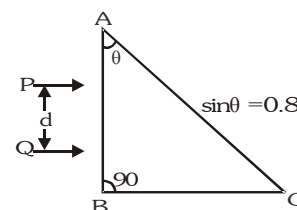
The value of b is such that the condition for total reflection at the face AC is just satisfied for one wavelength and is not satisfied for the other. A convergent lens is used to bring these transmitted beams into focus. If the intensities of the upper and the lower beams immediately after transmission from the face AC, are 4I and I respectively, find the resultant intensity at the focus.

8. A narrow monochromatic beam of light of intensity I is incident on a glass plate as shown in figure. Another identical glass plate is kept close to the first one & parallel to it. Each glass plate reflects 25% of the light incident on it & transmits the remaining. Find the ratio of the minimum & the maximum intensities in the interference pattern formed by the two beams obtained after one reflection at each plate.
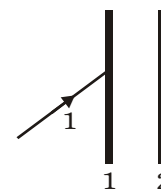
BRAIN STORMING SUBJECTIVE EXERCISE	ANSWER KEY	EXERCISE–4(B)

1. $4 \quad 10^{-15} \text{ W/m}^2$

2. $\dfrac{n\lambda D'}{d}$, $-D'$ where $D' = D + \dfrac{Mg}{K}(1 - \cos\omega t)$

3. (i) $t_B = 120 \ \mu m$ (ii) $\beta = 6mm$, $I_{max} = 9I$, $I_{min} = I$ (iii) $\dfrac{\beta}{6} = 1mm$ (iv) 9I, 3I

4. 3:4   **5.** $\dfrac{2(a+b)\lambda}{4a\theta}$ **6.** (i) 1mm (ii) increases   **7.** 9I   **8.** 1:49

EXERCISE–05(A)   PREVIOUS YEARS QUESTIONS

1. To demonstrate the phenomenon of interference we require two sources which emit radiations of-
   (1) nearly the same frequency   (2) the same frequency   **[AIEEE - 2003]**
   (3) different wavelength   (4)the same frequency and having a definite phase relationship

2. The maximum number of possible interference maxima for slit-separation equal to twice the wavelength in Young's double-slit experiment, is-   **[AIEEE - 2004]**
   (1) infinite   (2) five   (3) three   (4) zero

3. A Young's double slit experiment uses a monochromatic source. The shape of the interference fringes formed on a screen is-   **[AIEEE - 2005]**
   (1) hyperbola   (2) circle   (3) straight line   (4) parabola

4. In a Young's double slit experiment the intensity at a point where the path difference is $\dfrac{\lambda}{6}$ (λ being the wavelength of the light used) is I. If I_0 denotes the maximum intensity, I/I_0 is equal to-   **[AIEEE - 2007]**

   (1) $\dfrac{1}{\sqrt{2}}$ (2) $\dfrac{\sqrt{3}}{2}$ (3) $\dfrac{1}{2}$ (4) $\dfrac{3}{4}$

5. A mixture of light, consisting of wavelength590 nm and an unknown wavelength, illuminates Young's double slit and gives rise to two overlapping interference patterns on the screen. The central maximum of both lights coincide. Further, it is observed that the third bright fringe of known light coincides with the 4th bright fringe of the unknown light. From this data, the wavelength of the unknown light is :-   **[AIEEE - 2009]**
   (1) 442.5 nm   (2) 776.8 nm   (3) 393.4 nm   (4) 885.0 nm

Direction : Questions are based on the following paragraph.

An initially parallel cylindrical beam travels in a medium of refractive index $\mu(I) = \mu_0 + \mu_2 I$, where μ_0 and μ_2 are positive constants and I is the intensity of the light beam. The intensity of the beam is decreasing with increasing radius.   **[AIEEE - 2010]**

6. The initial shape of the wavefront of the beam is :-
   (1) planar   (2) convex
   (3) concave   (4) convex near the axis and concave near the periphery

7. The speed of the light in the medium is :-
   (1) maximum on the axis of the beam   (2) minimum on the axis of the beam
   (3) the same everywhere in the beam   (4) directly proportional to the intensity I

8. As the beam enters the medium, it will :
   (1) travel as a cylindrical beam   (2) diverge
   (3) converge   (4) diverge near the axis and converge near the periphery

9. At two points P and Q on screen in Young's double slit experiment, waves from slits S_1 and S_2 have a path difference of 0 and $\dfrac{\lambda}{4}$ respectively. the ratio of intensities at P and Q will be :   **[AIEEE - 2011]**

   (1) 3 : 2   (2) 2 : 1   (3) $\sqrt{2}$: 1   (4) 4 : 1

10. In a Young's double slit experiment, the two slits act as coherent sources of waves of equal amplitude A and wavelength λ. In another experiment with the same arrangement the two slits are made to act as incoherent sources of waves of same amplitude and wavelength. If the intensity at the middle point of the screen in the first case is I_1 and in the second case I_2, then the ratio $\dfrac{I_1}{I_2}$ is :- **[AIEEE - 2011]**

(1) 4   (2) 2   (3) 1   (4) 0.5

11. **Direction :** The question has a paragraph followed by two statement, Statement-1 and statement-2. Of the given four alternatives after the statements, choose the one that describes the statements.

A thin air film is formed by putting the convex surface of a plane-convex lens over a plane glass plate. With monochromatic light, this film gives an interference pattern due to light reflected from the top (convex) surface and the bottom (glass plate) surface of the film **[AIEEE - 2011]**

Statement-1: When light reflects from the air-glass plate interface, the reflected wave suffers a phase change of π.

Statement-2: The centre of the interference pattern is dark.

(1) Statement-1 is true, Statement-2 is true and Statement-2 is not the correct explanation of Statement-1.

(2) Statement-1 is false, Statement-2 is true

(3) Statement-1 is true, Statement-2 is false

(4) Statement-1 is true, Statement-2 is true and Statement-2 is the correct explanation of statement-1.

12. In Young's double slit experiment, one of the slit is wider than other, so that the amplitude of the light from one slit is double of that from other slit. If I_m be the maximum intensity, the resultant intensity I when they interfere at phase difference ϕ is given by : **[AIEEE - 2012]**

(1) $\dfrac{I_m}{9}(1 + 8\cos^2\dfrac{\phi}{2})$ (2) $\dfrac{I_m}{9}(4 + 5\cos\phi)$ (3) $\dfrac{I_m}{3}(1 + 2\cos^2\dfrac{\phi}{2})$ (4) $\dfrac{I_m}{5}(1 + 4\cos^2\dfrac{\phi}{2})$

13. Two coherent point sources S_1 and S_2 are separated by a small distance 'd' as shown. The fringes obtained on the screen will be : **[JEE Mains - 2013]**
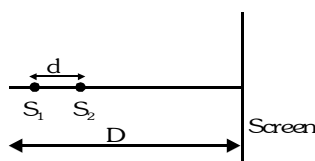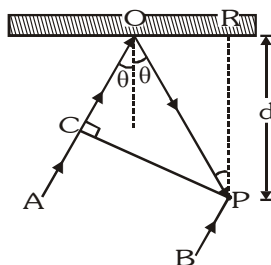

(1) points   (2) straight lines   (3) semi-circles   (4) concentric circles

PREVIOUS YEARS QUESTIONS			ANSWER KEY								EXERCISE −5(A)	
Que.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
Ans.	4	2	1	4	1	1	2	3	2	2	4	1	4

EXERCISE–05(B) PREVIOUS YEARS QUESTIONS

MCQ's (only one correct answers)

1. Two beams of light having intensifies I and 4I interfere to produce a fringe pattern on a screen. The phase difference between the beams on a screen. The phase difference between the beams is $\pi/2$ at point A and π at point B. Then the difference between resultant intensifies at A and B is **[IIT-JEE 2001]**
   (A) 2I   (B) 4I   (C) 5I   (D) 7I

2. In the ideal double–slit experiment, when a glass–plate (refractive index 1.5) of thickness t is introduced in the path of one of the interfering beams (wavelength λ), the intensity at the position where the central maximum occurred previously remains unchanged. The minimum thickness of the glass–plate is :– **[IIT-JEE 2002]**

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

3. In the adjacent diagram, CP represent a wavefront and AO and BP, the corresponding two rays. Find the condition on θ for constructive interference at P between the ray BP and reflected ray OP :– **[IIT-JEE 2003]**

   (A) $\cos\theta = \dfrac{3\lambda}{2d}$ (B) $\cos\theta = \dfrac{\lambda}{4d}$ (C) $\sec\theta - \cos\theta = \dfrac{\lambda}{d}$ (D) $\sec\theta - \cos\theta = \dfrac{4\lambda}{d}$

4. In a YDSE bi–chromatic light of wavelengths 400nm and 560 nm are used. The distance between the slits is 0.1 mm and the distance between the plane of the slits and the screen is 1m. The minimum distance between two successive regions of complete darkness is :– **[IIT-JEE 2004]**
   (A) 4 mm   (B) 5.6 mm   (C) 14 mm   (D) 28 mm

5. In Young's double slit experiment intensity at a point is (1/4) of the maximum intensity. Angular position of this point is :– **[IIT-JEE 2005]**

   (A) $\sin^{-1}\left(\dfrac{\lambda}{d}\right)$ (B) $\sin^{-1}\left(\dfrac{\lambda}{2d}\right)$ (C) $\sin^{-1}\left(\dfrac{\lambda}{3d}\right)$ (D) $\sin^{-1}\left(\dfrac{\lambda}{4d}\right)$

6. In the Young's double slit experiment using a monochromatic light of wavelength λ, the path difference (in terms of an integer n) corresponding to any point having half the peak intensity is :- **[IIT-JEE 2013]**

   (A) $(2n+1)\dfrac{\lambda}{2}$ (B) $(2n+1)\dfrac{\lambda}{4}$ (C) $(2n+1)\dfrac{\lambda}{8}$ (D) $(2n+1)\dfrac{\lambda}{16}$

MCQ's (one or more than one correct answers)

1. In a Young's double slit experiment, the separation between the two slits is d and the wavelength of the light is λ. The intensity of light falling on slit 1 is four times the intensity of light falling on slit 2. Choose the correct choice (s) **[IIT-JEE 2008]**
   (A) If d = λ, the screen will contain only one maximum
   (B) If $\lambda < d < 2\lambda$, at least one more maximum (besides the central maximum) will be observed on the screen
   (C) If the intensity of light falling on slit 1 is reduced so that it becomes equal to that of slit 2, the intensities of the observed dark and bright fringes will increase.
   (D) If the intensity of light falling on slit 2 is increased so that it becomes equal to that of slit 1, the intensities of the observed dark and bright fringes will increase

Comprehension Based Question

The figure shows a surface XY separating two transparent media, medium–1 and medium–2. The lines ab and cd represent wavefronts of a light wave travelling in medium–1 and incident XY. The lines ef and gh represent wavefronts of the light wave in medium–2 after refraction. **[IIT-JEE 2007]**

1. Light travels as a :–
   (A) parallel beam in each medium
   (B) convergent beam in each medium
   (C) divergent beam in each medium
   (D) divergent beam in one medium and convergent beam in the other medium
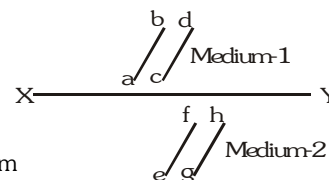
2. The phases of the light wave at c, d, e and f are ϕ_c, ϕ_d, ϕ_e and ϕ_f respectively. It is given that $\phi_c \neq \phi_f$:–
   (A) ϕ_c cannot be equal to ϕ_d
   (B) ϕ_d can be equal to ϕ_e
   (C) $(\phi_d - \phi_f)$ is equal to $(\phi_c - \phi_e)$
   (D) $(\phi_d - \phi_c)$ is not equal to $(\phi_f - \phi_e)$

3. Speed of light is :–
   (A) the same in medium–1 and medium–2
   (B) larger in medium–1 then in medium–2
   (C) larger in medium–2 than in medium–1
   (D) different at b and d

Match the Column

1. Column I shows four situations of standard Young's double slit arrangement with the screen placed far away from the slits S_1 and S_2. In each of these cases $S_1P_0 = S_2P_0$, $S_1P_1 - S_2P_1 = \lambda/4$ and $S_1P_2 - S_2P_2 = \lambda/3$, where λ is the wavelength of the light used. In the cases B, C and D, a transparent sheet of refractive index μ and thickness t is passed on slit S_2. The thicknesses of the sheets are different in different cases. The phase difference between the light waves reaching a point P on the screen from the two slits is denoted by $\delta(P)$ and the intensity by $I(P)$. Match each situation given in **Column I** with the statement(s) in Column II valid for that situation. **[IIT-JEE 2009]**

Column-I
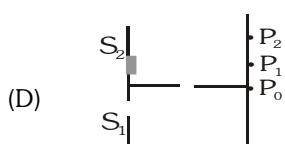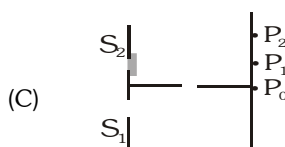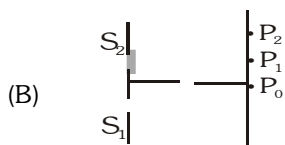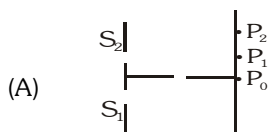
(A)
(B) $(\mu-1)t = \lambda/4$
(C) $(\mu-1)t = \lambda/2$
(D) $(\mu-1)t = 3\lambda/4$

Column-II

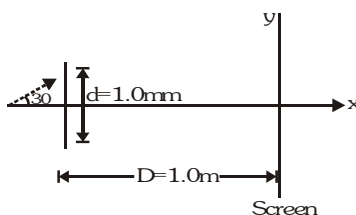(p) $\delta(P_0) = 0$
(q) $\delta(P_1) = 0$
(r) $I(P_1) = 0$
(s) $I(P_0) > I(P_1)$
(t) $I(P_2) > I(P_1)$

<u>Subjective Questions</u>

1. A coherent parallel beam of microwaves of wavelength λ = 0.5 mm falls on a Young's double slit apparatus. The separation between the slits is 1.0 mm. The intensity of microwaves is measured on a screen placed parallel to the plane of the slits at a distance of 1.0m from it as shown in the figure. **[IIT-JEE 1998]**

(i) If the incident beam falls normally on the double slit apparatus, find the y–coordinates of all the interference minima on the screen.

(ii) If the incident beam makes an angle of 30° with the x–axis (as in the dotted arrow shown in figure), find the y–coordinates of the first minima on either side of the central maximum.

2. The Young's double slit experiment is done in a medium of refractive index 4/3. A light of 600 nm wavelength is falling on the slits having 0.45 mm separation. The lower slit S_2 is covered by a thin glass sheet of thickness 10.4 µm and refractive index 1.5. The interference pattern is observed on a screen placed 1.5 m from the slits as shown in the figure. **[IIT-JEE 1999]**
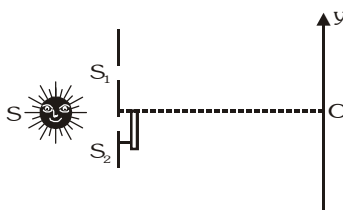

(i) Find the location of central max. (bright fringe with zero path difference) on the y–axis. (ii) Find the light intensity of point O relative to the maximum fringe intensity.

(iii) Now, if 600 nm light is replaced by white light of range 400 to 700 nm, find the wavelength of the light that form maxima exactly at point O. [All wavelengths in the problem are for the given medium of refractive index 4/3. Ignore dispersion]

3. A glass plate of refractive index 1.5 is coated with a thin layer of thickness t and refractive index 1.8. Light of wavelength λ travelling in air is incident normally on the layer. It is partly reflected at the upper and the lower surfaces of the layer and the two reflected rays interfere. Write the condition for their constructive interference. If λ = 648 nm, obtain the least value of t for which the rays interfere constructively.

[IIT-JEE 2000]

4. A vessel ABCD of 10cm width has two small slits S_1 and S_2 sealed with identical glass plates of equal thickness. The distance between the slits is 0.8 mm. POQ is the line perpendicular to the plane AB and passing through O, the middle point of S_1 and S_2. A monochromatic light source is kept at S, 40cm below P and 2m from the vessel, to illuminate the slits as shown in the figure alongside. Calculate the position of the central bright fringe on the other wall CD with respect to the line OQ. Now, a liquid is poured into the vessel and filled upto OQ. The central bright fringe is found to be at Q. Calculate the refractive index of the liquid.

[IIT-JEE 2001]
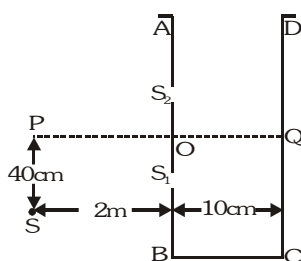
5. A point source S emitting light of wavelength 600nm is placed at a very small height h above a flat reflecting surface AB (see figure). The intensity of the reflected light is 36% of the incident intensity. Interference fringes are observed on a screen placed parallel to the reflecting surface at a very large distance D from it.

[IIT-JEE 2002]
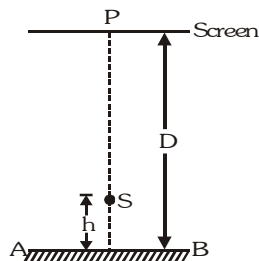
(i) What is the shape of the interference fringes on the screen ?

(ii) Calculate the ratio of the minimum to the maximum intensities in the interference fringes formed near the point P (shown in the figure).

(iii) If the intensity at point P corresponds to a maximum, calculate the minimum distance through which the reflecting surface AB should be shifted so that the intensity at P again becomes maximum.

6. In a Young's double slit experiment, two wavelengths of 500 nm and 700 nm were used. What is the minimum distance from the central maximum where their maximas coincide again ? Take $D/d = 10^3$. Symbols have their usual meanings. **[IIT-JEE 2004]**

PREVIOUS YEARS QUESTIONS	ANSWER KEY	EXERCISE –5(B)

- **MCQ's One correct answers**   1 B   2 A   3 B   4 D   5 C   6. B

- **MCQ's One correct answers**   1 A,B

- **Comprehension**   1. A   2. C   3. B

- **Match The Column**   1. (A)- p, s   (B) - q (C) - t (D) - r,s,t

- **Subjective**   1. (i) ± 0.26 m, ± 1.13 m (ii) 0.26m, 1.13 m

     2. (i) 4.33 m (ii) $I = \dfrac{3I_{max}}{4}$ (iii) 650 nm; 433.33 nm

     3. $2\mu t = \left(n - \dfrac{1}{2}\right)\lambda$ with $\mu = 1.8$ and n= 1,2,3,...90 , t_{min} = 90 nm

     4. 2 cm above point Q on side CD, μ= 1.0016

     5. (i) Circular (ii) $\dfrac{1}{16}$ (iii) 300 nm

     6. 3.5 mm