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

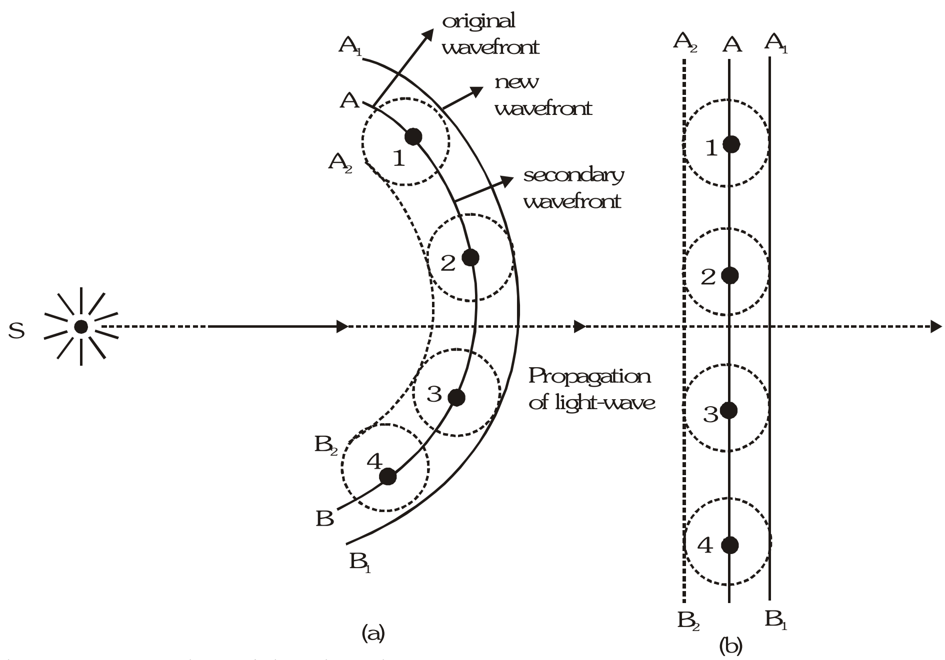
(i) The locus of all ether particles vibrating in same phase is known as wavefront.

(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.



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.

WAVE FRONT, VARIOUS TYPES OF WAVE FRONT AND RAYS

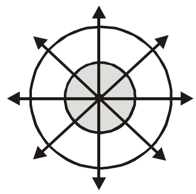
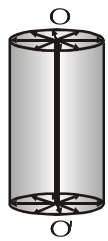
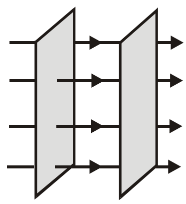
- **Wavefront**

  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		$A \propto \frac{1}{d}$ or $A \propto \frac{1}{r}$	$I \propto \frac{1}{r^2}$
2.	cylindrical	Linear or slit		$A \propto \frac{1}{\sqrt{d}}$ or $A \propto \frac{1}{\sqrt{r}}$	$I \propto \frac{1}{r}$
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 :

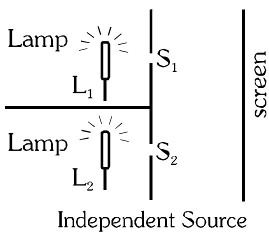
1. They are obtained from the same single source.

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.



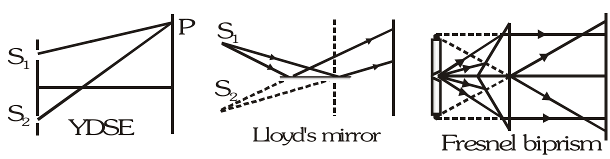
Independent Source (non-coherent source)

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.

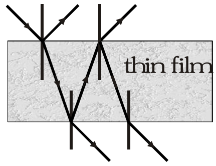
Example : Young's double slit experiment. Fresnel's Biprism and Lloyd's single mirror method.

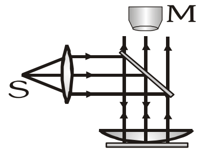


- **Division of amplitude**

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 $A = \sqrt{a_1^2 + a_2^2 + 2a_1a_2\cos\phi}$ and Phase angle $\theta = \tan^{-1}\dfrac{a_2 \sin\phi}{a_1 + a_2\cos\phi}$

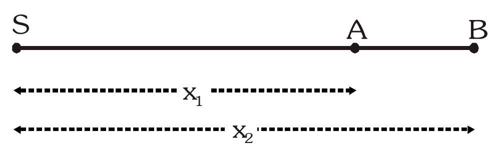
Intensity $\propto$ (Amplitude)^2 $\Rightarrow I \propto A^2 \Rightarrow I = KA^2$ so $I_1 = Ka_1^2$ & $I_2 = Ka_2^2$ $\therefore$ $I = I_1 + I_2 + 2\sqrt{I_1}\sqrt{I_2}\cos\phi$

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

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

TYPES OF INTERFERENCE

Constructive Interference

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

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

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

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

- 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 $\frac{\lambda}{2}$, $\delta = (2n-1)\frac{\lambda}{2}$, n = 1, 2 ...

- When time difference is an odd multiple of $\frac{T}{2}$, $\Delta t = (2n-1)\frac{T}{2}$, (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 $I_{av} = \frac{I_{max} + I_{min}}{2} = I_1 + I_2 = a_1^2 + a_2^2$

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

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

- Fringe visibility $V = \frac{I_{max} - I_{min}}{I_{max} + I_{min}} \times 100\%$ 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 $A = \sqrt{a_1^2 + a_2^2 + 2a_1a_2\cos\phi} = \sqrt{(4)^2 + (3)^2 + 2.(4)(3)\cos\frac{\pi}{3}} \Rightarrow A \simeq 6$

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

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

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

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

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

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

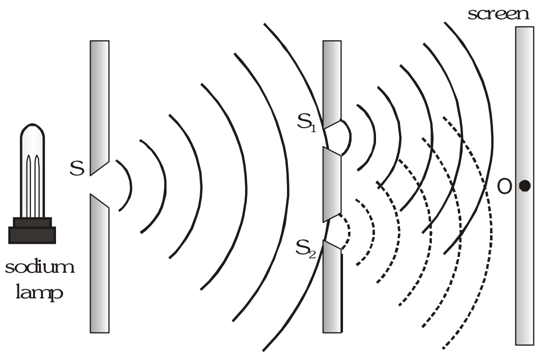
$$\phi_1 = \frac{2\pi\delta}{\lambda} \Rightarrow \frac{2\pi}{\lambda} \times \lambda = 2\pi \text{ and } \phi_2 = \frac{2\pi}{\lambda} \times \frac{\lambda}{4} = \frac{\pi}{2} \quad I_1 = I_0 + I_0 + 2\sqrt{I_0}\sqrt{I_0}\cos 2\pi = 4I_0$$

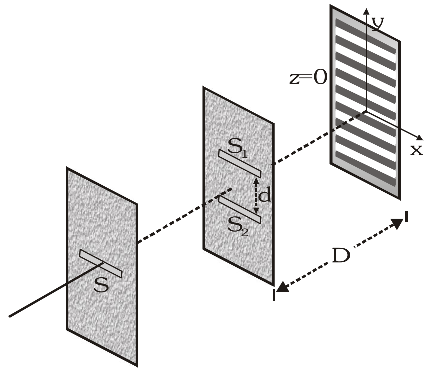
and $I_2 = I_0 + I_0 + 2\sqrt{I_0}\sqrt{I_0}\frac{\cos 2\pi}{2} = 2I_0 \quad \therefore \frac{I_1}{I_2} = \frac{4I_0}{2I_0} = 2 \quad \Rightarrow I_2 = \frac{I_1}{2} = \frac{K}{2}$ unit [$\because I_1 = K$ unit]

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

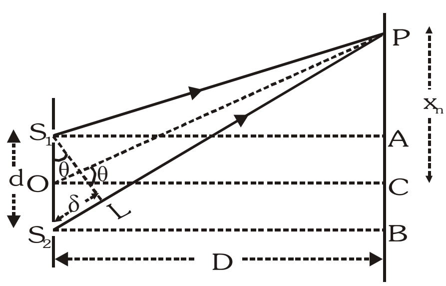
Bright Fringe

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 $\frac{\lambda}{2}$

$\therefore$ Path difference $\delta = PS_2 - PS_1 = S_2L = (2n)\frac{\lambda}{2}$



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

$\delta = n\lambda$ for bright fringes

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

The distance of n^{th} bright fringe from the central bright fringe $x_n = n\frac{D\lambda}{d}$

Dark Fringe

Dark fringe occurs due to destructive interference.

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

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

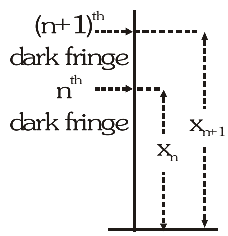
The distance of the m^{th} dark fringe from the central bright fringe $x_m = \frac{(2m-1)D\lambda}{2d}$

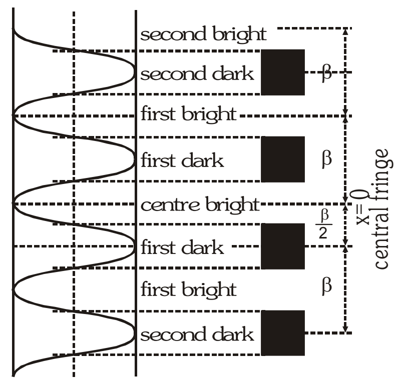
FRINGE WIDTH

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

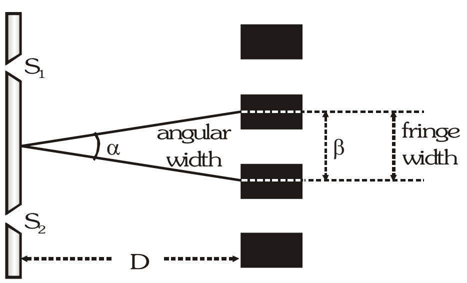
$$\beta = x_{n+1} - x_n = \frac{(n+1)D\lambda}{d} - \frac{nD\lambda}{d}$$

Fringe Width $\beta = \frac{D\lambda}{d}$





ANGULAR FRINGE WIDTH



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

- The distance of n^{th} bright fringe from the central bright fringe $x_n = \frac{n\lambda D}{d} = n\beta$
- The distance between n_1 and n_2 bright fringe $x_{n_2} - x_{n_1} = n_2\frac{\lambda D}{d} - n_1\frac{\lambda D}{d} = (n_2 - n_1)\beta$
- The distance of m^{th} dark fringe from central fringe $x_m = \frac{(2m-1)D\lambda}{2d} = \frac{(2m-1)\beta}{2}$
- The distance of n^{th} bright fringe from m^{th} dark fringe $x_n - x_m = n\frac{D\lambda}{d} - \frac{(2m-1)D\lambda}{2d} = n\beta - \frac{(2m-1)\beta}{2}$

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

GOLDEN KEY POINTS

- If the whole apparatus is immersed in a liquid of refractive index μ, then wavelength of light $\lambda' = \frac{\lambda}{\mu}$ 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 $\beta = \frac{\lambda D}{d}$ i.e. $\frac{\beta_2}{\beta_1} = \frac{\lambda_2}{\lambda_1} \Rightarrow \lambda_2 = \frac{\beta_2}{\beta_1} \times \lambda_1 = \frac{7.2}{8.1} \times 630 = 560$ 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 10^{th} maximum in radian and

(ii) Separation of the two adjacent minima.

Solution

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

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

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

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

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 $x'_m = (2m-1)\frac{D\lambda}{2d}$ given, D = 1m = 100 cm, d = 0.12 mm = 0.012 cm

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

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

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 = $\frac{4}{3}$).

Solution

$$\alpha_{air} = \frac{\lambda}{d} \Rightarrow \alpha_{air} = 0.2 \Rightarrow \alpha \propto \lambda \Rightarrow \frac{\alpha_w}{\alpha_{air}} = \frac{\lambda_w}{\lambda_{air}} \Rightarrow \lambda_w = \frac{\lambda_{air}}{\mu} \Rightarrow \alpha_w = \frac{\alpha_{air}\,\lambda}{\mu.\lambda} = \frac{0.2\times3}{4} = 0.15$$

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

According to question $0.01029 = \frac{343}{2}\lambda \Rightarrow \lambda = \frac{0.01029\times2}{343} = 6\times10^{-5}$ 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 ?

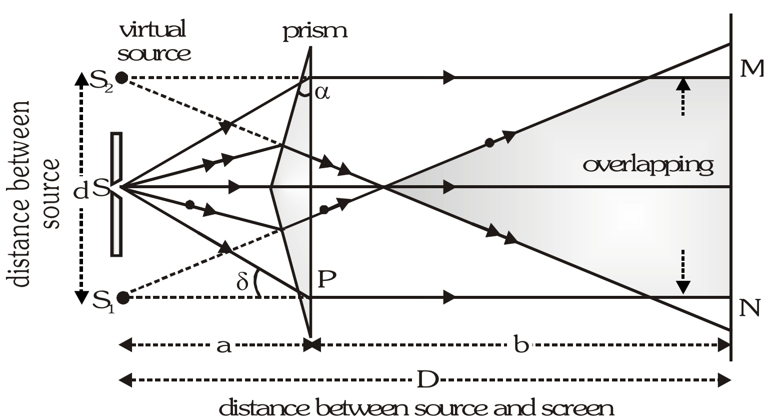
Solution

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

$$\alpha = \frac{\theta}{2} = \frac{1}{2}\left[\frac{\lambda}{d}\right] = \frac{1}{2}\left[\frac{5000\times\pi}{.1\times10^{-3}}\times10^{-10}\right]\frac{180}{\pi} = 0.45 .$$

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 $\frac{1^\circ}{2}$ or 1 . The fringes of equal width are observed in the limited region MN due to superposition.



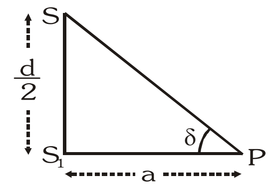
Distance between source and biprism = a

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



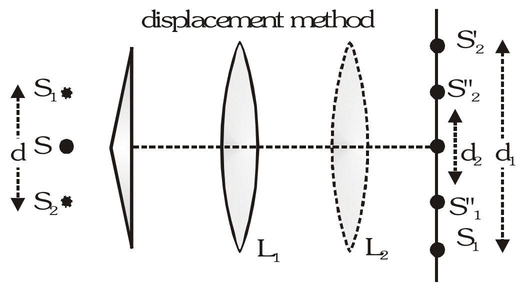
From ΔSS_1P $\tan\delta = \frac{d/2}{a}$ for very-very small δ hence $\tan\delta = \delta$ so $\delta = \frac{d}{2a} \Rightarrow d = 2a\delta$

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

- **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 $\beta = \frac{(a+b)\lambda}{\sqrt{d_1 d_2}}$



GOLDEN KEY POINTS

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

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

(ii) Separation between the two virtual sources decreases.

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

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

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

- 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

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

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

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

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

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

Example

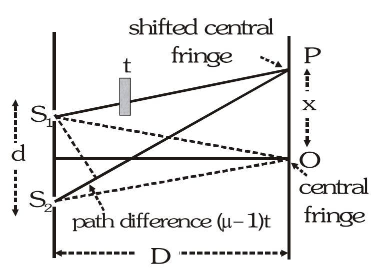
In fresnel's biprism experiment the distance between the source and the screen is 1m and that between the source and biprism is 10 cm. The wavelength of light used is 6000Å. The fringe width obtained is 0.03 cm and the refracting angle of biprism is 1 . Then calculate the refractive index of the material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

Solution

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

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_1P distance travelled by wave in air = $S_1P - t$



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

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

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

Example

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

Solution

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

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 $x = \frac{\beta(\mu_1 - \mu_2)t}{\lambda}$ $\because \frac{\beta}{\lambda} = \frac{D}{d}$

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.

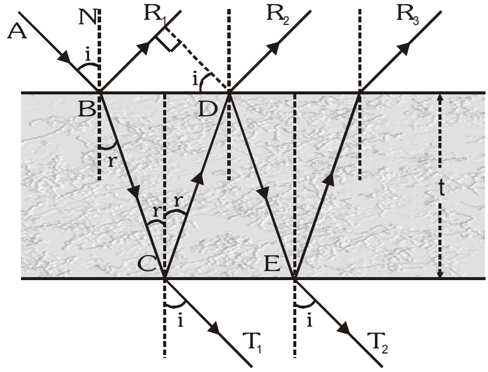
(i) The source of light must be an extended source

(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.



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

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

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

Example

Light is incident on a glass plate (μ = 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 $\quad 10^{-3}$ mm. calculate the order of the interference band.

Solution

μ= 1.5, r = 60 , λ = 6000Å = 6 $\quad 10^{-7}$ m $\Rightarrow$ t = 1.2 $\quad 10^{-3}$ = 1.2 $\quad 10^{-6}$ m

For dark band in the reflected light 2 μt cos r = nλ

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

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

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

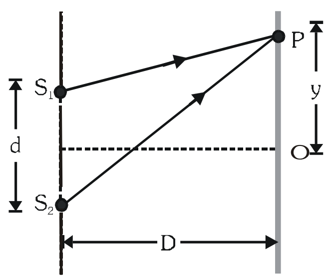
Example#2

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

(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 λ = 3cm we get y = ± 75 cm

Thus, the three maximas will be at y = 0 and y = ± 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

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

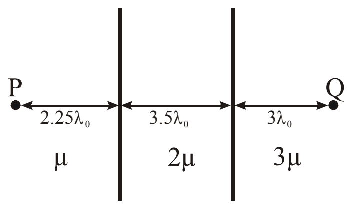
(b) When bright fringes coincide to each other then $n_1\lambda_1 = n_2\lambda_2 \Rightarrow \frac{n_1}{n_2} = \frac{\lambda_2}{\lambda_1} = \frac{5200Å}{6500Å} = \frac{4}{5}$

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

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

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 : μ=1]



(A) 0 (B) $\frac{\pi}{4}$ (C) $\frac{\pi}{2}$ (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 $\Delta\phi = \frac{2\pi}{\lambda_0} \times \Delta x = \frac{\pi}{2}$

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

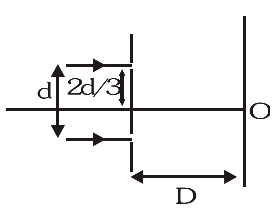
Solution **Ans. (B)**

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]



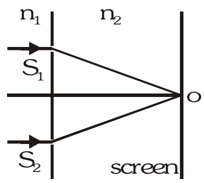
(A) 0 (B) d/2 (C) d/3 (D) d/6

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)**

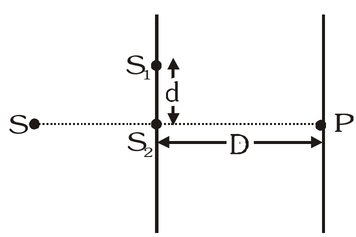
Path difference at O : $(\mu_{rel} - 1)\, t = \left(\frac{n}{n_2} - 1\right) t$

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

$\Rightarrow$ Phase difference$=\frac{\pi}{2} \Rightarrow$ 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 $D = \frac{8}{5}$ m. Source S starts moving from a very large distance towards S_2 perpendicular to S_1S_2 as shown in figure. The wavelength of 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)**

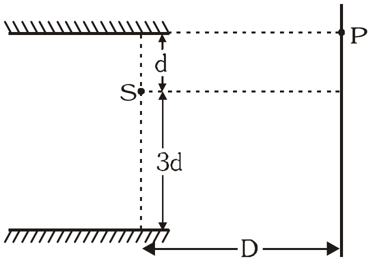
$$S_1P - S_2P = \frac{d^2}{2D} = \frac{2\times10^{-3}\times2\times0^{-3}}{2\times\frac{8}{5}} = \frac{5}{2}\lambda \quad (\lambda = 500\text{nm})$$

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.

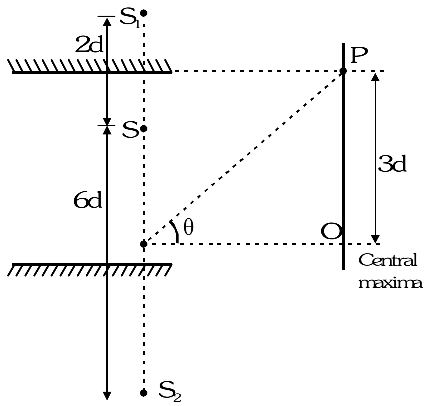
Example#9

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) $\frac{12d^2}{D}$ (B) $\frac{6d^2}{D}$ (C) $\frac{3d^2}{D}$ (D) $\frac{24d^2}{D}$

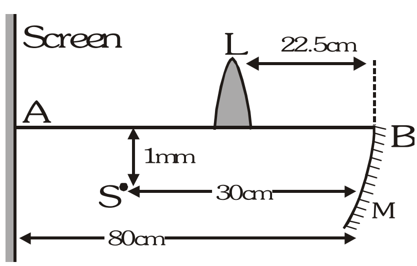
Solution **Ans. (A)**



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

Example#10 to12

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 $\frac{10}{3}$ cm and the lens is shifted towards right by 2.5 cm then-

(A) Fringe width remains same

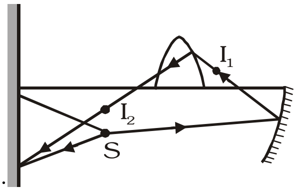
(B) Intensity of pattern will remain same

(C) Fringe width will change

(D) No interference pattern will form.

Solution

10. Ans. (B)



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

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

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 = $\frac{v}{u} = \frac{7.5}{-7.5} = -1$

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)

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

12. Ans. (D)

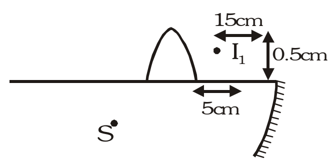


Image formed by the combination is I_2 at

$\frac{1}{v} - \frac{1}{-5} = \frac{3}{10} \Rightarrow v = 10$ 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

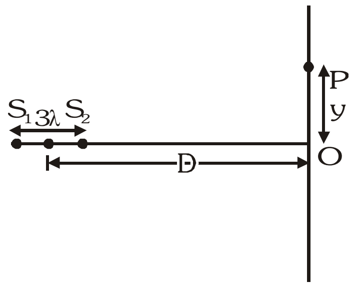
(C) Statement–1 is True, Statement–2 is False.

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

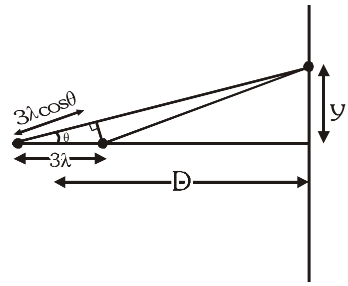
Solution Ans. (B)

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 λ <<D and y≠ 0, the minimum value of y for point P to be an intensity maximum is $\frac{\sqrt{m}\,D}{n}$. Determine the value of m + n, if m and n are coprime numbers.



Solution **Ans. (7)**

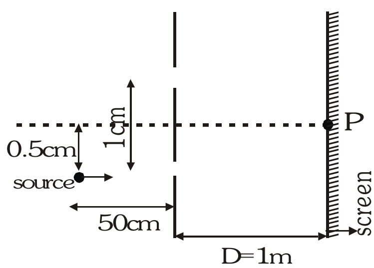


Path difference = $3\lambda\cos\theta = 2\lambda \Rightarrow \cos\theta = \frac{2}{3}$

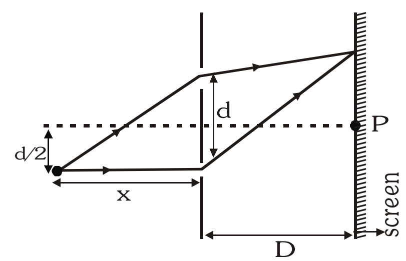
$y = D\tan\theta = \frac{D\sqrt{5}}{2} \Rightarrow m + n = 5 + 2 = 7$

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 $\alpha \quad 10^{-\beta}$ cm/s upward in scientific notation. Find the value of $\alpha+\beta$.



Solution **Ans. 5**



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

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

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

Select the correct alternative (only one correct answer)

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 exhibits 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 ωt and y_2 = a cos ωt. The first wave :–
(A) leads the second by π (B) lags the seconds by π (C) leads the second by $\frac{\pi}{2}$ (D) lags the seconds by $\frac{\pi}{2}$

10. The resultant amplitude of a vibrating particle by the superposition of the two waves
$y_1 = a\sin\left[\omega t + \frac{\pi}{3}\right]$ and y_2 = a sin ωt 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) $\frac{2\pi x}{\lambda}$ (B) $\frac{2\pi\lambda}{x}$ (C) $\frac{\pi x}{\lambda}$ (D) $\frac{\pi\lambda}{x}$

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 (λ = 5898Å), 92 fringes are seen. If given colour (λ = 5461Å) 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) $\frac{d}{D}(\mu-1)t$
(B) $\frac{D}{d}(\mu-1)t$
(C) $\frac{d}{(\mu-1)D}$
(D) $\frac{D}{d}(\mu-1)$

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 coloures between violet and red
(C) only the central fringe is white, all other fringes are coloured
(D) no fringes are observed

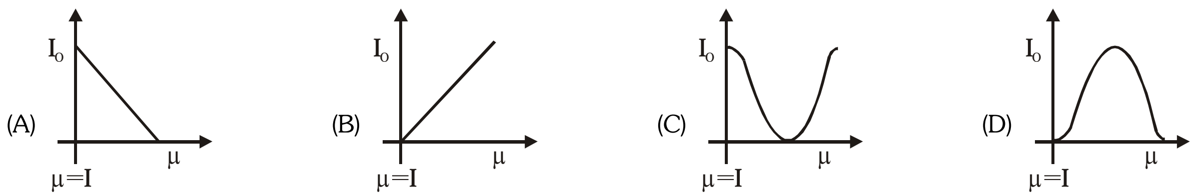
25. In the young's double slit experiment the central maxima is observed to be I_0. If one of the slits is covered, then intensity at the central maxima will become :–
(A) $\frac{I_0}{2}$
(B) $\frac{I_0}{\sqrt{2}}$
(C) $\frac{I_0}{4}$
(D) I_0

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

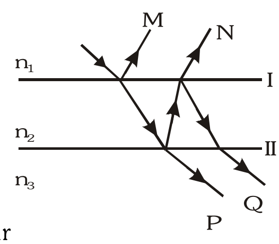
28. In YDSE, the source placed symmetrically with respect to the slit is now moved parallel to the plane of the slits it is closer to the upper slit, as shown. Then ,
(A) the fringe width will increase and fringe pattern will shift down.
(B) the fringe width will remain same but fringe pattern will shift 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 (μ ≥ 1). [Assume slits of equal width and there is no absorption by slab]



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.

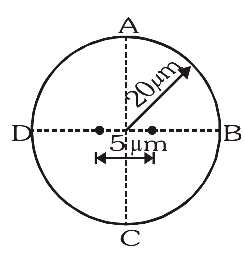
31. A ray of light is incident on a thin film. As shown in figure M, N are two reflected rays and P, Q are two transmitted rays, Rays N and Q undergo a phase change of π. Correct ordering of the refracting indices is :
(A) $n_2 > n_3 > n_1$ (B) $n_3 > n_2 > n_1$
(C) $n_3 > n_1 > n_2$ (D) none of these, the specified changes can not occur



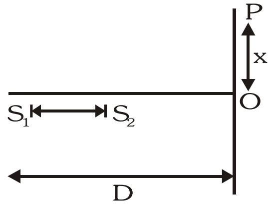
32. Let S_1 and S_2 be the two slits in Young's double slit experiment. If central maxima is observed at P and angle $\angle S_1PS_2 = \theta$, then the fringe width for the light of wavelength λ will be. (Assume θ to be a small angle)
(A) λ/θ (B) $\lambda\theta$ (C) $2\lambda/\theta$ (D) $\lambda/2\theta$

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 (>>λ) from the slits. The smallest distance x such that the P is a maxima.

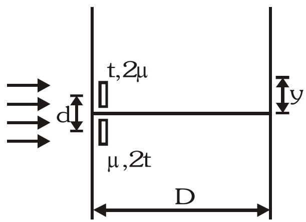


(A) $\sqrt{3}D$ (B) $\sqrt{8}D$ (C) $\sqrt{5}D$ (D) $\sqrt{5}\frac{D}{2}$

36. Minimum thickness of a mica sheet having $\mu = \frac{3}{2}$ 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) $\frac{tD}{d}$ (C) $-\frac{tD}{d}$ (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) $\frac{\pi}{3}$ (B) $\frac{13\pi}{3}$ (C) $\frac{17\pi}{3}$ (D) $\frac{11\pi}{3}$