CBSE Class 12 Physics Notes Chapter 10: CBSE Class 12 Physics Notes Chapter 10 Wave Optics explores the wave nature of light. It covers the concepts of interference, diffraction, and polarization, explaining how light waves superpose to form constructive and destructive interference patterns.

The chapter delves into Young's Double Slit Experiment (YDSE), which demonstrates the wave behavior of light through the creation of fringes. Diffraction is explained as the bending of light around obstacles, while polarization refers to the orientation of light waves. The chapter also discusses the Huygens Principle, which explains the propagation of light waves as wavefronts.

CBSE Class 12 Physics Notes Chapter 10 Overview

In "Wave Optics," Chapter 10 of CBSE Class 12 Physics, the wave nature of light is thoroughly examined and contrasted with the particle theory covered in previous chapters. Huygens' Principle, which asserts that each point on a wavefront serves as a source of secondary wavelets, opens the chapter. Understanding wave propagation, reflection, and refraction is based on this theory.

Young's Double Slit Experiment (YDSE), which illustrates the interference phenomena and offers compelling support for the wave theory of light, is one of the major experiments that is examined. This experiment demonstrates how constructive and destructive interference between two coherent light sources results in a pattern of bright and dark fringes.

The chapter also discusses diffraction, which is the process by which light bends around obstructions or holes to cause the wavefront to spread. Understanding this phenomenon is essential to comprehending the optical instruments' resolution limitations.

Another important topic is polarisation, which describes how light waves are orientated in specific directions and is not explained by the particle theory of light. There are real-world uses for this idea in the form of sunglasses and photo filters.

CBSE Class 12 Physics Notes Chapter 10 Wave Optics

Below we have provided CBSE Class 12 Physics Notes Chapter 10 Wave Optics -

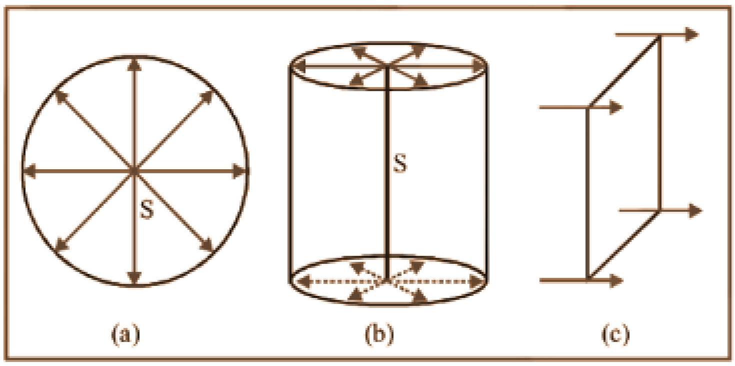
A place that generates disturbance in all directions is called a light source. Every particle in a homogeneous medium must always vibrate in phase with one another because the disturbance reaches all of the medium's particles in phase, which are all at the same distance from the light source. The wave front is the location of all the medium particles that are vibrating in the same phase at any one time.

Depending upon the shape of the source of light, wave front can be the following types:

- Spherical wavefront
- Cylindrical wavefront

Spherical Wave Front

A spherical wave front is produced by a point source of light. This is because a spherical figure (a) represents the location of each point that is equally spaced from the point source.



Cylindrical Wave Front

A slit or other linear light source creates a cylindrical wave front. Here, each point on the surface of a cylindrical figure (b) is equally spaced from the linear source.

Plane Wave Front

If a wave front is a tiny portion of a larger, distantly originating spherical or cylindrical wave front, it will seem planar. Thus, the term "plane wave front figure" (c) is used.

Ray of Light

A light ray is the route that light takes when travelling. A ray of light is represented by an arrow that is normal to the wave front and points in the disturbance's propagation direction. The light rays are represented by thick arrows in a ray diagram.

Because the light beam is normal to the wave front, it is also known as the wave normal.

Huygens's Principle

A wave front's new position at a later time can be obtained from its given position at any instant using Huygens' principle, a geometric construction. Alternatively put, this principle provides a method and an idea of how light diffuses in a material.

Based on the following presumptions, it is developed:

1. Every location on a specific primary wave front serves as a source of secondary wavelets, which, like the primary light source, radiate disruption in all directions.

2. The envelope of the secondary wavelets at any given time is the new position of the wave front, also referred to as the secondary wave front.

The Huygens principle, sometimes known as Huygens' construction, is based on these two presumptions.

Principle of Superposition

> If two or more than two waves superimpose each other at a common particle of the medium then the resultant displacement (y) of the particle is equal to the vector sum of the displacements (y_1 and y_2) produced by individual waves .i.e $\vec{y} = \vec{y_1} + \vec{y_2}$

Phase/Phase difference/Path difference/Time difference

> **i. Phase:** Phase is defined as the argument of sine or cosine in the expression for displacement of a wave. For displacement $y = a\sin\omega t$; term $\omega t =$ phase or instantaneous phase.
>
> **ii. Phase Difference (ϕ):** Phase difference is the difference between the phases of two waves at a point. i.e. if $y_1 = a_1\sin\omega t$ and $y_2 = a_2\sin(\omega t + \phi)$ so phase difference $= \phi$
>
> **iii. Path Difference (Δ):** Path difference between the waves at that point is the difference in path length's of two waves meeting at a point. Also $\Delta = \frac{\lambda}{2\pi} \times \phi$.
>
> **iv. Time Difference (T.D):** Time difference between the waves meeting at a point is given by T.D $= \frac{T}{2\pi} \times \phi$
>
> **3.3. Resultant Amplitude and Intensity**
> If we have two waves $y_1 = a_1\sin\omega t$ and $y_2 = a_2\sin(\omega t + \phi)$ where $a_1, a_2 =$ Individual amplitudes, $\phi =$ Phase difference between the waves at an instant when they are meeting a point. $I_1, I_2 =$ Intensities of Individual waves.
>
> **Resultant Amplitude:**
> After superimposition of the given waves resultant amplitude (or the amplitude of resultant wave) is given by $A = \sqrt{a_1^2 + a_2^2 + 2a_1a_2\cos\phi}$
>
> For the interfering waves $y_1 = a_1\sin\omega t$ and $y_2 = a_2\sin(\omega t + \phi)$, Phase difference between them is 90^o . So resultant amplitude $A = \sqrt{a_1^2 + a_2^2}$

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Resultant Intensity:

As we know intensity $\alpha(\text{Amplitude})^2 \Rightarrow I_1\text{-}ka_1{}^2, I_2\text{-}ka_2{}^2 \text{ and } I=kA^2(k$ is a proportionality constant) . Hence from the formula of resultant amplitude, we get the following formula of resultant intensity

$$I\text{-}I_1+I_2+2\sqrt{I_1I_2}\cos\phi$$

The term $2\sqrt{I_1I_2}\cos\phi$ is called interference term. For incoherent interference this term is zero so resultant intensity $I=I_1+I_2$

Coherent Sources

Light sources that emit continuous waves of the same wavelength, frequency, and phase, or with a consistent phase difference, are known as coherent sources.

Interference of Light

Interference of light occurs when two waves of the exact same frequency, originating from two coherent sources, superimpose simultaneously and travel in the same direction through a medium, causing the intensity of light to be at its highest at one location and at its lowest at another.

Constructive Interference

When two or more waves collide, their crests (peaks) and troughs (valleys) line up with one another. A wave with a bigger amplitude than the component waves is the outcome.

Example: Two sound waves of the same frequency and phase overlapping, creating a louder sound.

Destructive Interference

When the crest and trough of two waves collide, the amplitude of the waves decreases or cancels out completely if their amplitudes are identical.

Example: Noise-canceling headphones use destructive interference to cancel out ambient noise.

Resultant Intensity Due to Two Identical Waves

The resultant intensity for two coherent sources is given by

$$\mathrm{I} = \mathrm{I}_1 + \mathrm{I}_2 + 2\sqrt{\mathrm{I}_1 \mathrm{I}_2} \cos\phi$$

For identical source $\mathrm{I}_1 = \mathrm{I}_2 = \mathrm{I}_0$

$$\Rightarrow \mathrm{I} = \mathrm{I}_0 + \mathrm{I}_0 + 2\sqrt{\mathrm{I}_0 \mathrm{I}_0} \cos\phi = 4\mathrm{I}_0 \cos^2\frac{\phi}{2}$$

$$\left[1 + \cos\theta = 2\cos^2\frac{\theta}{2}\right]$$

Note:

- Redistribution of energy takes place in the form of maxima and minima in interference
- **Average Intensity:** $\mathrm{I}_{\mathrm{av}} = \frac{\mathrm{I}_{\max} + \mathrm{I}_{\min}}{2} = \mathrm{I}_1 + \mathrm{I}_2 = \mathrm{a}_1{}^2 + \mathrm{a}_2{}^2$
- **Ratio of Maximum and Minimum Intensities:** $\frac{I_{\max}}{I_{\min}} = \left(\frac{\sqrt{I_1} + \sqrt{I_2}}{\sqrt{I_1} - \sqrt{I_2}}\right)^2 \left(\frac{\sqrt{I_1/I_2} + 1}{\sqrt{I_1/I_2} - 1}\right)^2 = \left(\frac{a_1 + a_2}{a_1 - a_2}\right)^2 = \left(\frac{a_1/a_2 + 1}{a_1/a_2 - 1}\right)^2$
- Also $\sqrt{\frac{I_1}{I_2}} = \frac{a_1}{a_2} = \left(\frac{\sqrt{\frac{I_{\max}}{I_{\min}}} + 1}{\sqrt{\frac{I_{\max}}{I_{\min}}} - 1}\right)$
- If two waves having equal intensity $(\mathrm{I}_1 = \mathrm{I}_2 = \mathrm{I}_0)$ meets at two locations P and Q with path difference Δ_1 and Δ_2 respectively then the ratio of resultant intensity at point
- P and Q will be $\frac{I_p}{I_Q} = \frac{\cos^2\frac{\phi_1}{2}}{\cos^2\frac{\phi_2}{2}} = \frac{\cos^2\left(\frac{\pi\Delta_1}{\lambda}\right)}{\cos^2\left(\frac{\pi\Delta_2}{\lambda}\right)}$

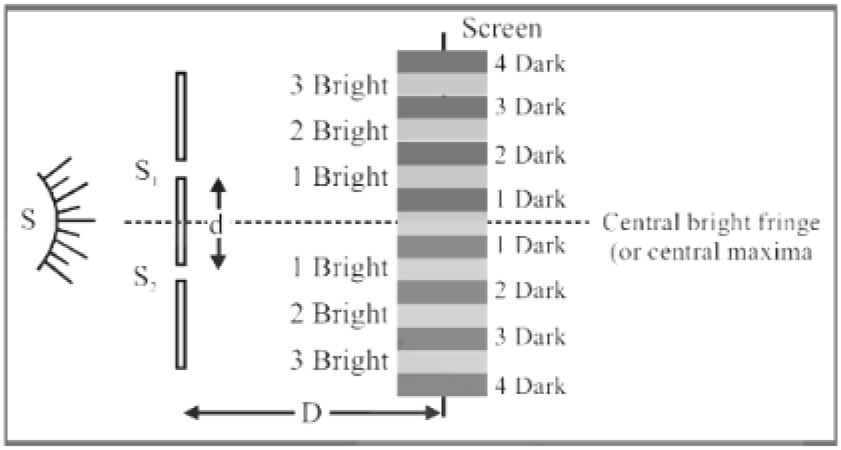
Young’s Double Slit Experiment (YDSE)

When monochromatic light (single wavelength) falls on two very close narrow slits, S1 and S2, it operates as two coherent sources, and when waves from these two sources superimpose on one other, an interference pattern is produced on the screen. The experiment produced alternating bands of light and dark on the screen. We refer to these groups as Fringes.

d= Distance between slits.

D= Distance between slits and screen

λ=Wavelength of monochromatic light emitted from source.



1. At the centre, where either Δ=0 or ϕ=0. Thus, there will always be light at the central edge.

2. A slit will produce a brighter fringe pattern than one caused by a point.

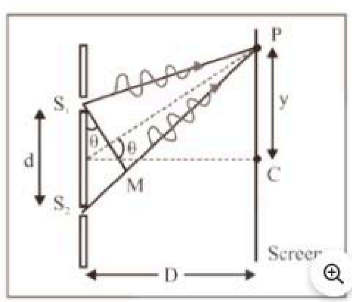
3. If the slit widths are not identical, the minima won't be totally dark. Hence, there is consistent lighting over a fairly wide area.

4. If one slit is lit with red light and the other with blue light, there is no discernible interference pattern on the screen.

5. If an object and its reflected image make up the two coherent sources, the central fringe will be dark rather than dazzling.

Path Difference

Path difference between the interfering waves meeting at a point P on the screen is given by $\mathrm{x}=\frac{\mathrm{yd}}{\mathrm{D}}=\mathrm{d}\sin\theta$ where x is the position of point P from central maxima.



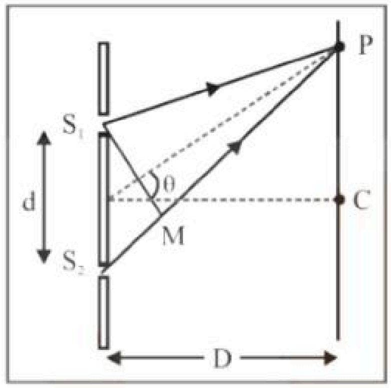
For maxima at P: $\mathbf{x}=\mathbf{n}\lambda$

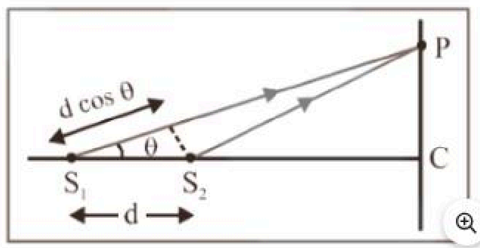
Where $n=0,\pm1,\pm2,\ldots$

And for minima at P: $x=\frac{(2n-1)\lambda}{2}$

Where $n=0,\pm1,\pm2,\ldots$

If the slits are horizontal path difference is $d\cos\theta$,so as θ increases,x decreases. But if the slits are vertical, the path difference $(x)$is $d\sin\theta$, so as θ increases,Δ also increases.





More About Fringes:

(i) Every fringes will have equal width. Width of one fringe is $\beta = \frac{\lambda D}{d}$ and angular fringe width $\theta = \frac{\lambda}{d}$

(ii) If the YDSE setup is taken in one medium then changes into another, so β changes. E.g. in water $\lambda_w = \frac{\lambda_a}{\mu_w} \Rightarrow \beta_w = \frac{\beta_a}{\mu_w} = \frac{3}{4}\beta_a$

(iii) Fringe width $\beta \propto \frac{1}{d}$ i.e if separation between the sources increases, β decreases.

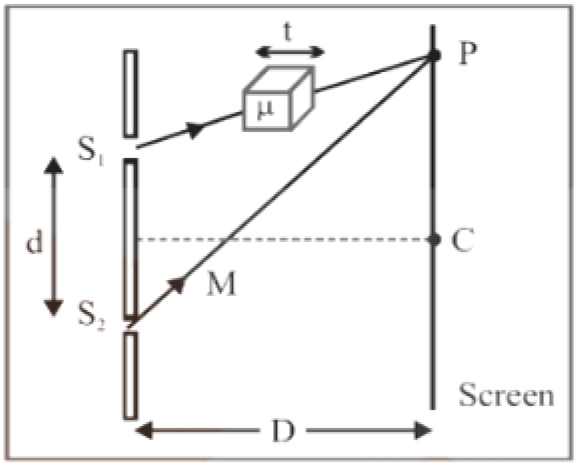
(iv) Position of n^{th} bright fringe from central maxima $x_n = \frac{n\lambda D}{d} = n\beta; n = 0, 1, 2, ..$

(v) Position of n^{th} dark fringe from central maxima $x_n = \frac{(2n-1)\lambda D}{2d} = \frac{(2n-1)\beta}{2}; n = 1, 2, 3, ..$

(vi) In YDSE, if n_1 fringes are visible in a field of view with light of wavelength λ_1 , while n_2 with light of wavelength λ_2 in the same field, then $n_1\lambda_1 = n_2\lambda_2$

Shifting of Fringe Pattern in YDSE

A transparent thin film of glass or mica in the course of one of the waves will cause the fringe pattern to change. The pattern shifts upward if the film is positioned in the upper wave's route and downward if it is positioned in the lower wave's path.



Fringe shift $= \frac{D}{d}(\mu\text{-}1)\,t = \frac{\beta}{\lambda}(\mu\text{-}1)\,t$

⇒ Additional path difference $= (\mu - 1)\,t$

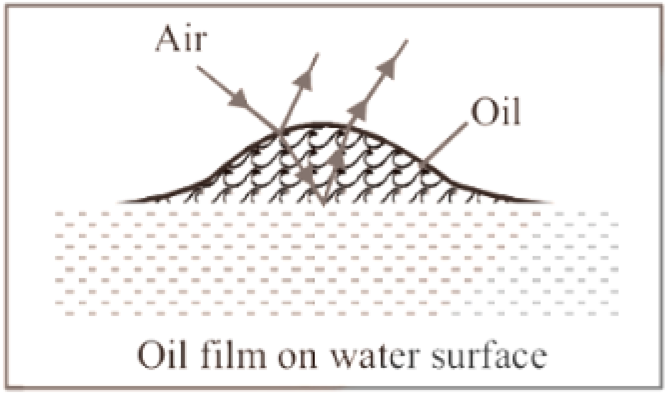
⇒If the shift is equivalent to $n$fringes, then $n = \frac{(\mu\text{-}1)t}{\lambda}$ or $t = \frac{n\lambda}{(\mu\text{-}1)}$

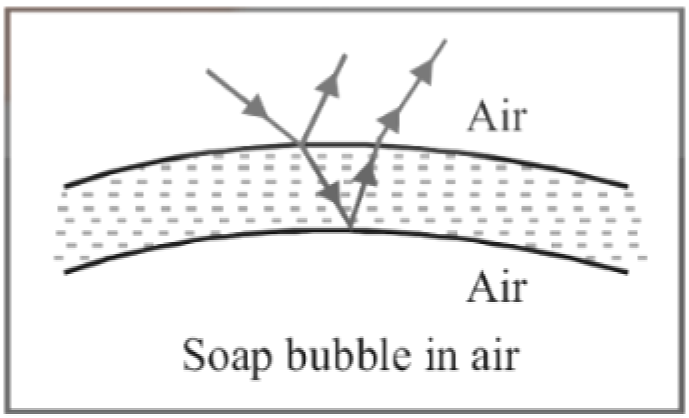
⇒Fringe shift is independent of the order of fringe (i.e shift of zero order maxima = shift of n^{th} order maxima)

⇒Also, the shift is independent of wavelength.

Illustrations of Interference

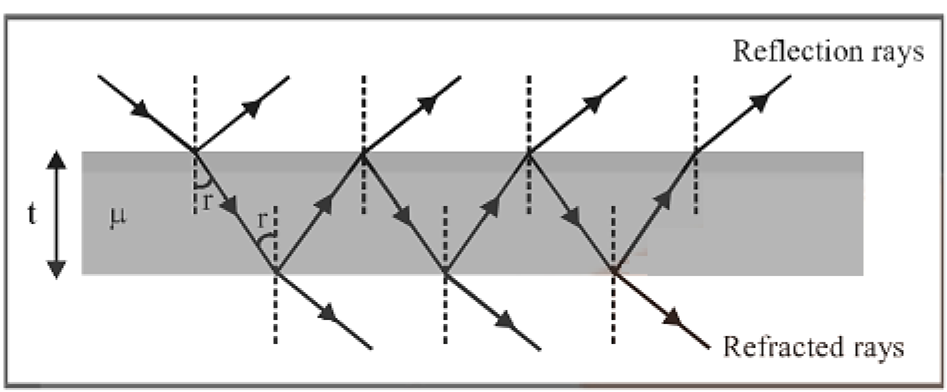
When the thickness of a thin film is similar to the wavelength of incident light, interference effects are frequently seen (if the film is too thick, this will return in uniform illumination of the film; if it is too thin as compared to wavelength of light, it seems dark). Because of the interference of waves reflected from the two surfaces of the film, a thin coating of oil on the water's surface and soap bubbles seem different colours in white light.





Thin Films

In case of thin films, interference occur between the waves reflected from its two surfaces and waves refracted through it.



Doppler's Effect in Light

The phenomenon due to relative motion between the source of light and the observer which causes apparent change in frequency (or wavelength) of the light is called Doppler's effect.

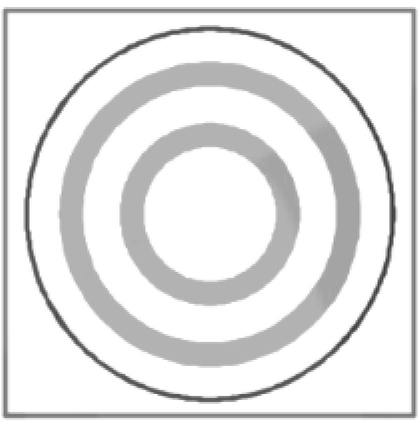
According to special theory of relativity,

$$\frac{v'}{v}=\frac{1\pm v/c}{\sqrt{1-v^2/c^2}}$$

If v =actual frequency, v' = apparent frequency,v = speed of source with respect to stationary observer, c = speed of light.

Diffraction and Optical Instruments

An instrument's objective lens, such as a telescope, microscope, etc., functions as a circular aperture. Through light diffraction at the circular aperture, a converging lens creates an Airy disc—a brighter disc encircled by alternating dark and bright concentric rings—instead of a point image of an object.



The angular half width of Airy disc$=\theta=\frac{1.22\lambda}{D}$ (where D = aperture of lens)

The lateral width of the image = $f\theta$ (where f = focal length of the lens)

Polarization of Light

EM waves that flow transversely are light. The electric field's magnitude is significantly greater than the magnetic field's. Light is typically described as oscillations in an electric field.

Polaroid

A Polaroid is the gadget that creates the planar polarised light. The idea of selective absorption serves as its foundation. It works better than the tourmaline crystal as well.

It is also known as a thin layer of quinine sulphate crystals, each of which has an optic axis parallel to the other.

(i) Only light oscillations parallel to the transmission axis are permitted to pass through a Polaroid.

(ii) A polariser is a crystal or Polaroid that receives incident light that is not polarised. An analyser is a crystal or polaroid that receives incident polarised light.

Malus Law

When polarised light passes through an analyser, its intensity varies proportionally to the square of the cosine of the angle formed by the analyzer's transmission plane and the polarizer's plane of incidence. We call this Malus law.

$$\mathrm{I}=\mathrm{I_o}\cos^2\theta \text{and } \mathrm{A}^2=\mathrm{A_o}^2\cos^2\theta \Rightarrow \mathrm{A}=\mathrm{A_o}\cos\theta$$

If $\theta=0^\circ, \mathrm{I}=\mathrm{I_o}, \mathrm{A}=\mathrm{A_o}$

If $\theta=45^\circ, \mathrm{I}=\frac{\mathrm{I_o}}{2}, \mathrm{A}=\frac{\mathrm{A_o}}{\sqrt{2}}$

If $\theta=90^\circ, \mathrm{I}=0, \mathrm{A}=0$

(ii) If $I_i =$ Intensity of unpolarised light.

So, $I_o = \frac{I_i}{2}$ i.e. if an unpolarised light is converted into plane polarized light (say by passing it through a Polaroid or a Nicole-prism), its intensity becomes half and $\mathrm{I}=\frac{\mathrm{I_i}}{2}\cos^2\theta$

Note:

Percentage of polarisation$= \frac{(I_{\max}-I_{\min})}{(I_{\max}+I_{\min})} \times 100$

Benefits of CBSE Class 12 Physics Notes Chapter 10

The benefits of studying the CBSE Class 12 Physics Notes for Chapter 10 "Wave Optics" include:

Conceptual Clarity: The notes provide a clear understanding of complex topics such as interference, diffraction, and polarization, which are crucial for mastering wave optics.

Exam Preparation: Summarized points, key formulas, and important concepts are highlighted, making it easier for students to revise and prepare effectively for board exams.

Problem-Solving Skills: By understanding the wave nature of light, students can approach and solve related numerical problems with greater confidence.

Foundation for Higher Studies: The chapter lays the groundwork for advanced studies in fields like optics, photonics, and quantum mechanics, essential for careers in physics and engineering.

Practical Applications: The concepts of wave optics are directly linked to real-world applications, such as in optical instruments, lasers, and communication technologies, helping students appreciate the relevance of what they are learning.