Optics

Interference, Diffraction, Polarization

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Huygens Principal

According to Huygens, a light source in a *homogeneous isotropic medium* sends out light in every direction & these waves travel with equal velocity to carry energy with them to be transmitted in all directions.

1. Every point on a given wavefront may be regarded as the source of a new disturbance, called **secondary wavelets.**
2. The secondary wavelets(spherical) from each point spread out in all directions with the velocity of light.
3. The envelope of these wavelets in the forward direction at any instance constitutes the new wave front at the instance.

Wavefront- defined as a *surface* on which the phase of the disturbance is the same at any given instant of time. (two types = spherical /cylindrical)

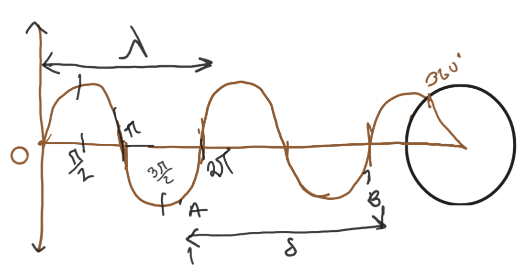
Huygens Principal can

- Refraction & reflection. Double Refraction in crystals.
-

Huygens Principal cannot

- Geometrical shadow theory.
- Diffraction interference.

Path Difference vs Phase Difference



Suppose 2 points $A\,and\,B$

path difference $OB - OA = \delta$

let, Phase difference $= \theta$

we know if the difference between two waves equals to its wavelength(λ) then $\theta = 2\pi\,[360°]$

for path distance λ phase diff $= 2\pi$

for path distance δ phase diff $= \dfrac{2\pi}{\lambda}\theta$

so, $\boxed{\theta = 2\pi\delta/\lambda}$

Coherent Source: the phase diff between the interfering waves must be zero or constant.

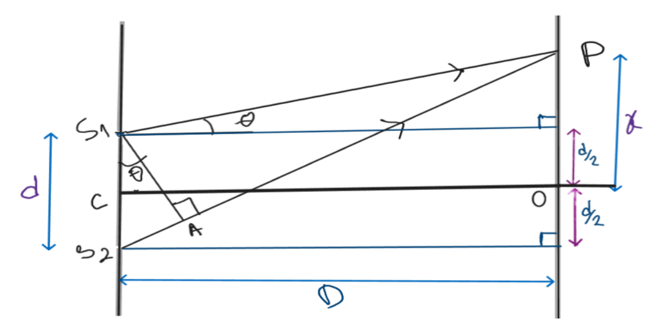
Interference

Superposition stats that.. the resultant disturbance of two or more waves acting on the same point simultaneously is the vector sum of the individual waves(disturbances).

$$
\begin{aligned}
&\text{Let, } y_1 = a\sin\omega t, \text{ and } \; y_2 = a\sin(\omega t + \theta),\\
&\text{so, resultant will, } y = y_1 + y_2\\
&\qquad = a[\sin\omega t + \sin(\omega t + \theta)]\\
&\qquad = 2a\sin(\omega t + \frac{\theta}{2})\sin\frac{\theta}{2}\\
&\qquad = A\sin(\omega t + \frac{\theta}{2})
\end{aligned}
$$

Interference of light - the phenomenon where *monochromatic* light waves coming from two or more *coherent sources* Superimpose, This leads to regions of constructive interference (brighter) and destructive interference (darker), creating an interference pattern.

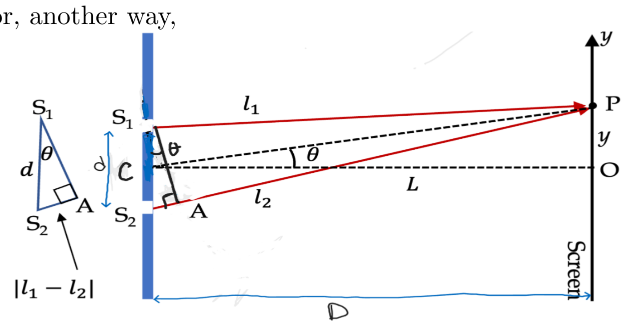
Young's Double slit Experiment



$$
\begin{aligned}
&l_1^2 = D^2 + (x - d/2)^2\\
&l_2^2 = D^2 + (x + d/2)^2\\
&\text{so, } (l_1 + l_2)(l_1 - l_2) = (x - d/2)^2 - (x + d/2)^2\\
&\implies (l_1 - l_2)\,2D = 2xd\\
&\implies l_1 - l_2 = path\,difference,
\end{aligned}
$$

$$\therefore \boxed{\delta = \mathbf{xd/D}}$$

or, another way,



$$
\begin{aligned}
&S_2A = \delta = S_1P - S_2P = l_1 - l_2, \quad (D = CP)\\
&\text{and in } \triangle S_1AS_2, \quad \sin\theta = S_2A/S_1S_2\\
&\qquad\qquad \text{or,} \quad S_2A = \delta = d\sin\theta\\
&P\,\&\,O \text{ are very close when, } S_1P \approx S_2P \approx D\\
&\text{as } [d << D] \text{ and } y \text{ is very small}\\
&\text{then, } \theta = \angle S_2S_1A = \angle PCO\\
&\therefore \quad \delta = d\sin\theta = \frac{dy}{PC} \approx \frac{dy}{D}\;[if,\; S_1S_2 = 2d \implies \frac{2dy}{D}]
\end{aligned}
$$

now, *from principle of interference we know, resultant amplitude*

$$A = 2a\cos\left(\frac{\theta}{2}\right) = 2a\cos\left(\frac{2\pi\delta}{2\lambda}\right)$$

$$\delta = \lambda\sigma/2\pi$$

Conditions for sustained interference:

- must be coherent(same λ or θ), so we **can't use two real sources** they can't be coherent.(also $a_1 \neq a_2$)
- same frequency(f) or wavelength(λ). **so,** if we cover slits with different transparent color paper that's lead to $\lambda_a \neq \lambda_b$
- if Polarized, then must be in same state of Polarization
- medium matters cause in water, $\beta' = \frac{D\lambda'}{d} = \beta' = \frac{D}{d}\frac{\lambda}{\mu}$ so, $\beta' < \beta$,means width will reduced.

Conditions for good observation:

- d must be small, **but if** $d < \lambda$ then β is extremely large, lead to an **uniform illumination** got **no visible fringes**. $[\beta \propto (\lambda/d)]$
- D should be relatively large. $\beta \propto D$
- Background should be darker.

Conditions for good contrast:

- amplitudes should be equal or very nearly equal $I_m \propto (a_1 \pm a_2)^2$ so, $a_1 \approxeq a_2$
- the sources must be narrow
- sources must be monochromatic or very nearly so.

Conservation of energy in interference: In case of constructive interference, $I = I_{max}$ and bright fringes are formed in the screen. Whereas in case of destructive interference, $I = I_{min}$, dark fringes are formed.

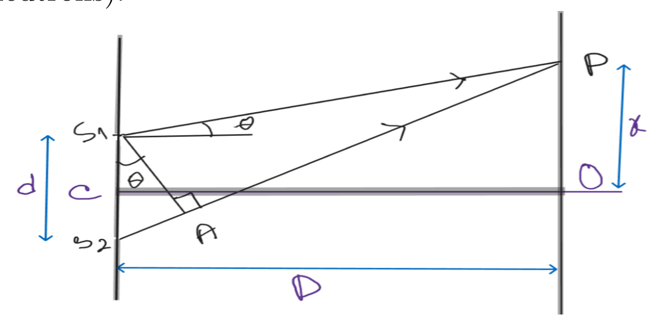
This implies that in interference and diffraction pattern, the intensity of light is simply being redistributed **i.e. energy is only transferred from dark to bright fringe and no energy is created or destroyed in the process.**

$$\begin{aligned} I_{\text{total}} &= I_1 + I_2 \\ &= I_1 + I_2 + 2\sqrt{I_1 I_2}\ \cos\phi \end{aligned}$$

Diffraction

The phenomenon of bending of light waves around obstacles or (aperture of sizes comparable with the wavelengths of light) & resulting thereby in their spreading in *Geometrical shadow* of the object is known as Diffraction.

It is a fundamental phenomenon in wave physics that occurs with all types of waves, including sound waves, electromagnetic waves (such as visible light, X-rays, and radio waves), and even matter waves (such as electrons and neutrons).



path difference, $\delta = l_1 - l_2$,
and in $\triangle S_1AS_2$, $\sin\phi = S_2A/S_1S_2$
or, $\delta = d\sin\phi$
so, phase difference, $\theta = \frac{2\pi}{\lambda}\delta = \frac{2\pi}{\lambda}a\sin\phi$

The key aspects of diffraction are:

- **Bending of waves around obstacles:** When waves encounter an obstacle or an edge, they tend to bend around it, rather than traveling in a straight line.
- **Spreading of waves through apertures:** When waves pass through a small opening or aperture, they spread out and diverge, rather than traveling in a straight beam.
- **Interference patterns:** The bending and spreading of waves can create interference patterns, where the waves constructively and destructively interfere with each other, leading to regions of higher and lower intensity.

Types of diffraction

1. **Fresnel type** the source and the screen *(i.e. the point of observation)* or both are at finite distance from the obstacle or the aperture.
2. **Fraunhofer's type** both source and screen are *at* ∞ *distance* from each other.