PHY 203- PHYSICS III

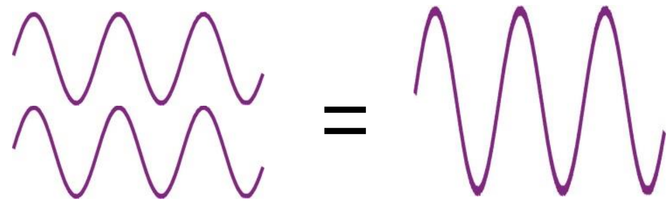
Interference

Constructive vs. destructive interference; Coherent vs. incoherent interference

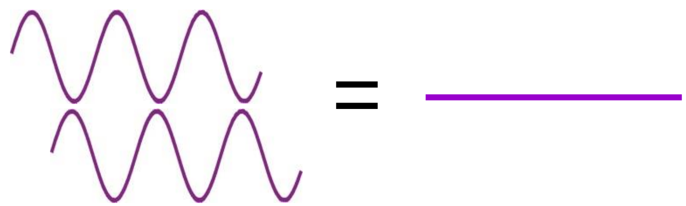
Waves that combine **in phase** add up to relatively high irradiance.

Waves that combine **180° out of phase** cancel out and yield zero irradiance.

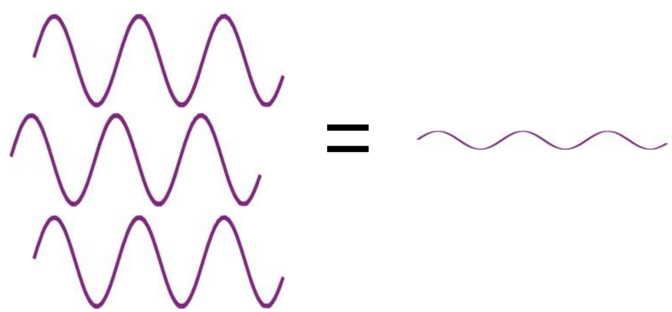
Waves that combine with **lots of different phases** nearly cancel out and yield very low irradiance.



Constructive interference (coherent)



Destructive interference (coherent)



Incoherent addition

Can we observe interference from two lightbulbs?

- If two lightbulbs are placed side by side, no interference effects are observed because the light waves from one bulb are emitted independently of those from the other bulb. The emissions from the two lightbulbs do not maintain a constant phase relationship with each other over time. Light waves from an ordinary source such as a lightbulb undergo random phase changes in time intervals less than a nanosecond. Because the eye cannot follow such rapid changes, no interference effects are observed. Such light sources are said to be ***incoherent***.

Interference conditions in light waves

- The sources must be coherent—that is, they must maintain a constant phase with respect to each other.

- The sources should be monochromatic—that is, of a single wavelength.

As an example, single-frequency sound waves emitted by two side-by-side loudspeakers driven by a single amplifier can interfere with each other because the two speakers are coherent—that is, they respond to the amplifier in the same way at the same time.

Common way for producing two coherent light source:

- The light emerging from the two slits is coherent because a single source produces the original light beam and the two slits serve only to separate the original beam into two parts. Any random change in the light emitted by the source occurs in both beams at the same time.
- (a) If light waves did not spread, the waves would not overlap and no interference pattern would be seen.
- (b) This divergence of light from its initial line of travel is called diffraction.

Example – **Measuring the Wavelength of a Light Source**

A viewing screen is separated from a double-slit source by 1.2 m. The distance between the two slits is 0.030 mm. The second-order bright fringe (m = 2) is 4.5 cm from the center line.

(A) Determine the wavelength of the light.

(B) Calculate the distance between adjacent bright fringes.

$m = 2$, $y_{bright} = 4.5 * 10^{-2}$ m, $L = 1.2$ m, and $d = 3.0 * 10^{-5}$ m:

(A)

$$\lambda = \frac{y_{\text{bright}} d}{mL} = \frac{(4.5 \times 10^{-2}\ \text{m})(3.0 \times 10^{-5}\ \text{m})}{2(1.2\ \text{m})}$$

$$= 5.6 \times 10^{-7}\ \text{m} = \boxed{560\ \text{nm}}$$

(B)

$$y_{m+1} - y_m = \frac{\lambda L}{d}(m+1) - \frac{\lambda L}{d} m$$

$$= \frac{\lambda L}{d} = \frac{(5.6 \times 10^{-7}\ \text{m})(1.2\ \text{m})}{3.0 \times 10^{-5}\ \text{m}}$$

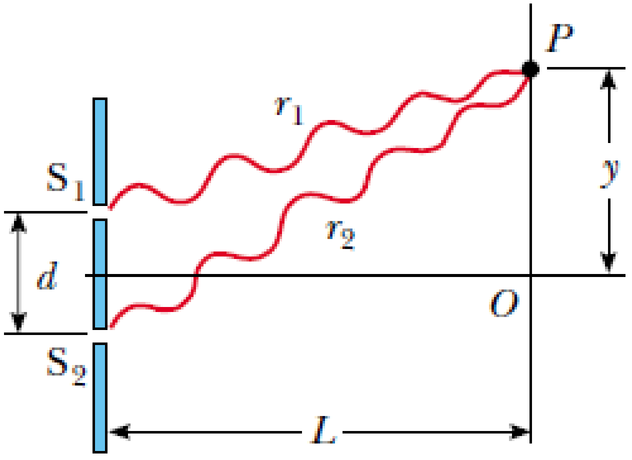
$$= 2.2 \times 10^{-2}\ \text{m} = \boxed{2.2\ \text{cm}}$$

Intensity Distribution of the Double-Slit Interference Pattern

Let's calculate the distribution of light intensity at point P:

$$I \alpha E_P^2 \quad \Rightarrow \quad E_P = E_1 + E_2$$

$$E_1 = E_0 \sin \omega t \qquad E_2 = E_0 \sin(\omega t + \phi)$$



Phase difference due to the path difference:

$$\phi = k(r_2 - r_1) = \frac{2\pi}{\lambda}\delta = \frac{2\pi}{\lambda} d \sin\theta$$

$$E_P = E_1 + E_2 = E_0[\sin \omega t + \sin(\omega t + \phi)]$$

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Trigonometriden

$$\sin A + \sin B = 2 \sin\left(\frac{A+B}{2}\right)\cos\left(\frac{A-B}{2}\right)$$

$A = \omega t + \phi$ **ve** $B = \omega t,$

$$E_P = 2E_0 \cos\left(\frac{\phi}{2}\right)\sin\left(\omega t + \frac{\phi}{2}\right)$$

$$I \propto {E_P}^2 = 4E_0^2 \cos^2\left(\frac{\phi}{2}\right)\sin^2\left(\omega t + \frac{\phi}{2}\right)$$

Sumary:

- Interference of two light waves on a given point depends on the relative phases of the waves at that point.

- The pahases between waves depend on the path difference of the waves.

- Light intensity of the interfered waves at a point :