

# Wave Optics Overview



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## Coherent and Incoherent Addition of Waves

### Interference Pattern through Superposition of Waves

- **Principle:** At any specific point in a medium, the resultant displacement produced by multiple waves is the vector sum of the displacements of individual waves.

### Constructive and Destructive Interference

- **Constructive Interference:**

- Occurs when the phase difference between two waves is an integer multiple of  $2\pi$  or the path difference is an integer multiple of the wavelength  $\lambda$ .
- Condition for constructive interference at a point  $P$ :

$$S_1P - S_2P = n\lambda \quad (n = 0, 1, 2, \dots)$$

- The resultant intensity at this point will be maximum, given by:

$$I = 4I_0$$

- Here,  $I_0$  is the intensity due to each individual wave.

- **Destructive Interference:**

- Occurs when the phase difference is an odd multiple of  $\pi$  (half-integral multiples of the wavelength).
- Condition for destructive interference at a point  $P$ :

$$S_1P - S_2P = \left(n + \frac{1}{2}\right)\lambda \quad (n = 0, 1, 2, \dots)$$

- The resultant intensity at this point will be zero.

### Resultant Displacement and Intensity at Arbitrary Points

- For two waves  $y_1 = a \cos \omega t$  and  $y_2 = a \cos(\omega t + \phi)$  with a phase difference  $\phi$ :
  - Resultant displacement:

$$y = y_1 + y_2 = 2a \cos\left(\frac{\phi}{2}\right) \cos\left(\omega t + \frac{\phi}{2}\right)$$

- Resultant amplitude:

$$A = 2a \cos\left(\frac{\phi}{2}\right)$$

○ Resultant intensity:

$$I = 4I_0 \cos^2\left(\frac{\phi}{2}\right)$$

## Coherence and Phase Stability

### • Coherent Sources:

○ If two sources have a constant phase difference (maintained over time), the interference pattern (positions of maxima and minima) is stable.

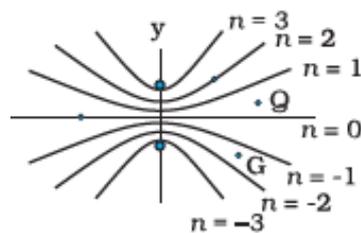
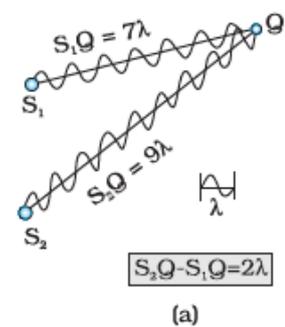
### ○ Incoherent Sources:

- If the phase difference between sources varies randomly over time, the interference pattern will vary.
- The observed intensity will be the **time-averaged intensity**, given by:

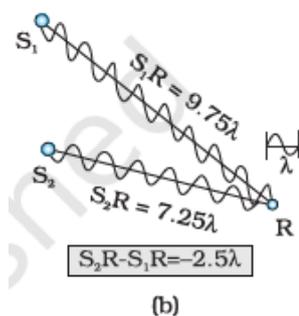
$$\langle I \rangle = 2I_0$$

## Summary

- Constructive interference yields maximum intensity, while destructive interference leads to zero intensity.
- Coherent sources produce a stable interference pattern, whereas incoherent sources result in a time-averaged intensity due to random phase variations.



**FIGURE 10.10** Locus of points for which  $S_1P - S_2P$  is equal to zero,  $\pm\lambda$ ,  $\pm 2\lambda$ ,  $\pm 3\lambda$ .



**FIGURE 10.9**  
 (a) Constructive interference at a point Q for which the path difference is  $2\lambda$ .  
 (b) Destructive interference at a point R for which the path difference is  $2.5\lambda$ .