

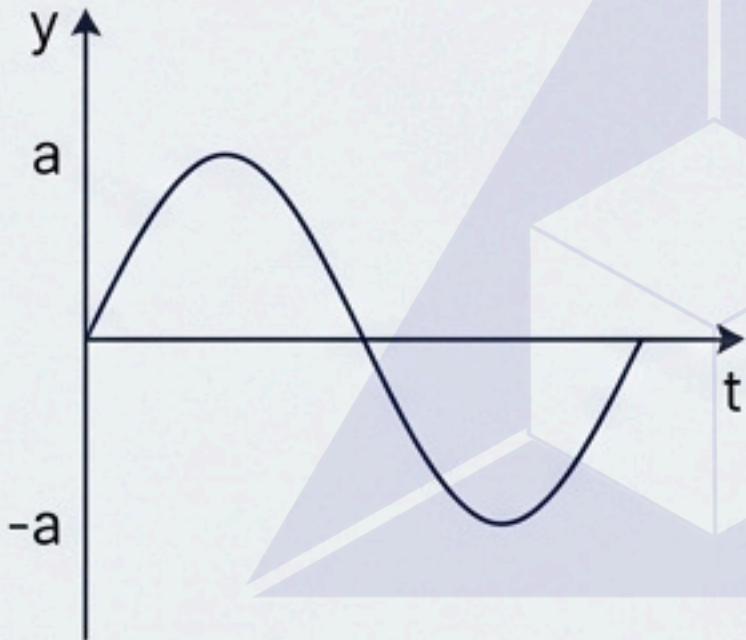
H1 Coherent and Incoherent Addition of Waves

H2 Why some waves form stable patterns

A visual guide to Class 12 Wave Optics (Section 10.4).

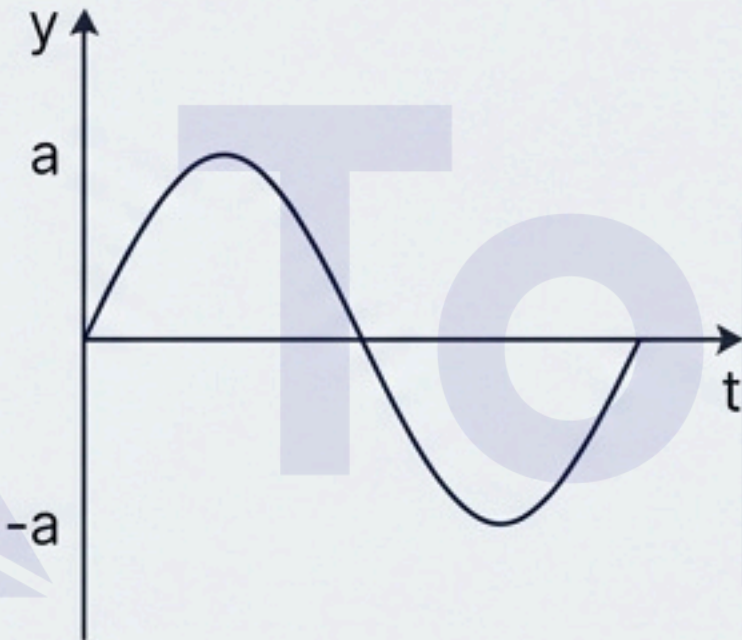
The Superposition Principle

At any point in a medium, the resultant displacement produced by multiple waves is the **exact vector sum** of the displacements produced by each individual wave.



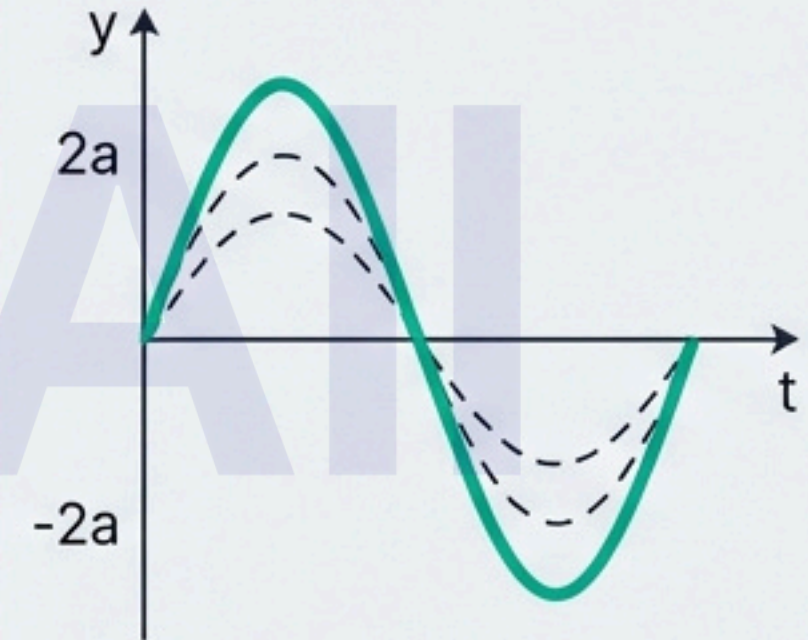
Wave A
 $y_1 = a \cos \omega t$

+



Wave B
 $y_2 = a \cos \omega t$

=

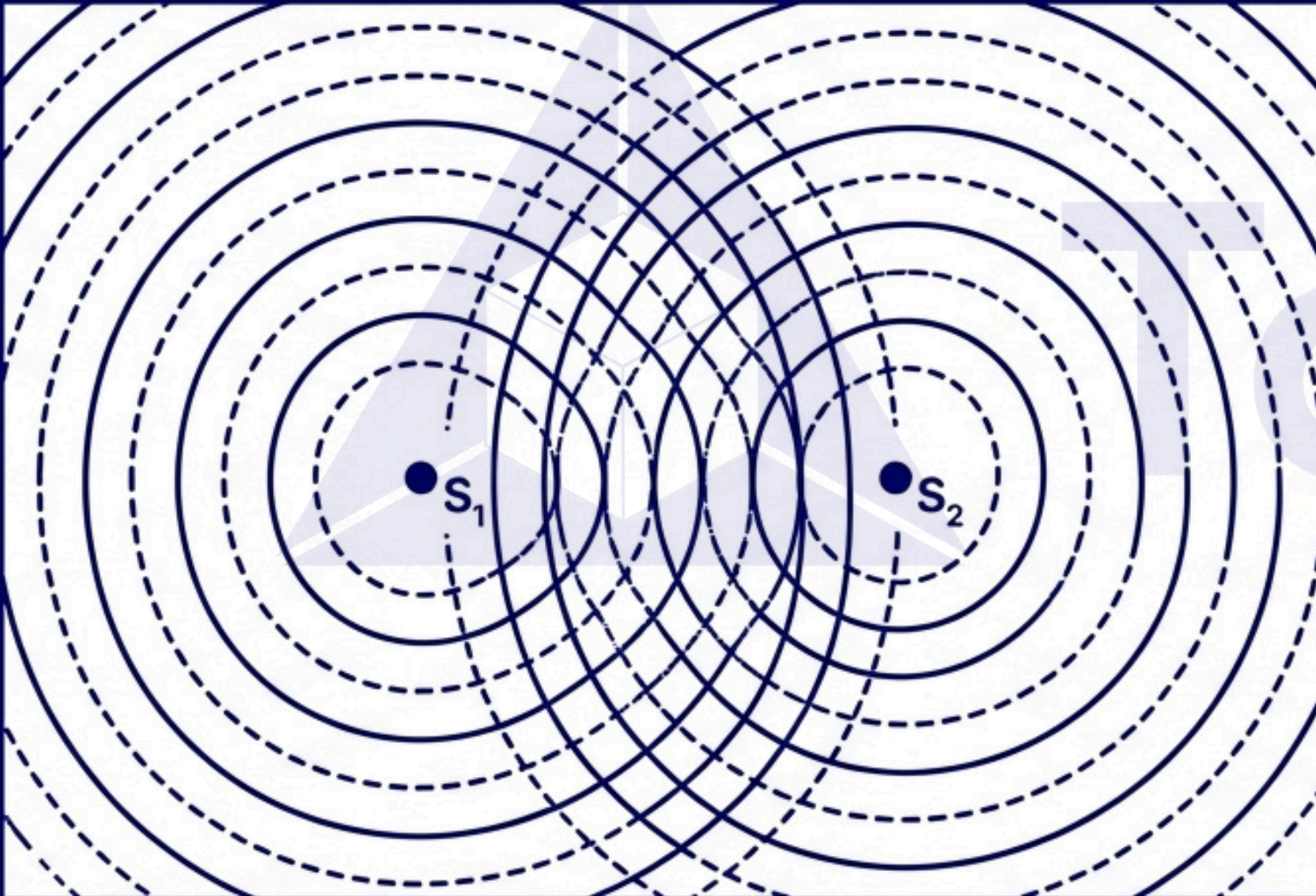


Resultant Wave
 $y = y_1 + y_2 = 2a \cos \omega t$

Coherent Sources: The Prerequisite for Stability



Imagine two identical needles (S_1 and S_2) oscillating up and down in a water trough. Because they are driven by the same mechanism, they act as perfectly synchronized sources.



The Coherence Condition

Sources are coherent if the phase difference between their displacements remains completely constant over time.



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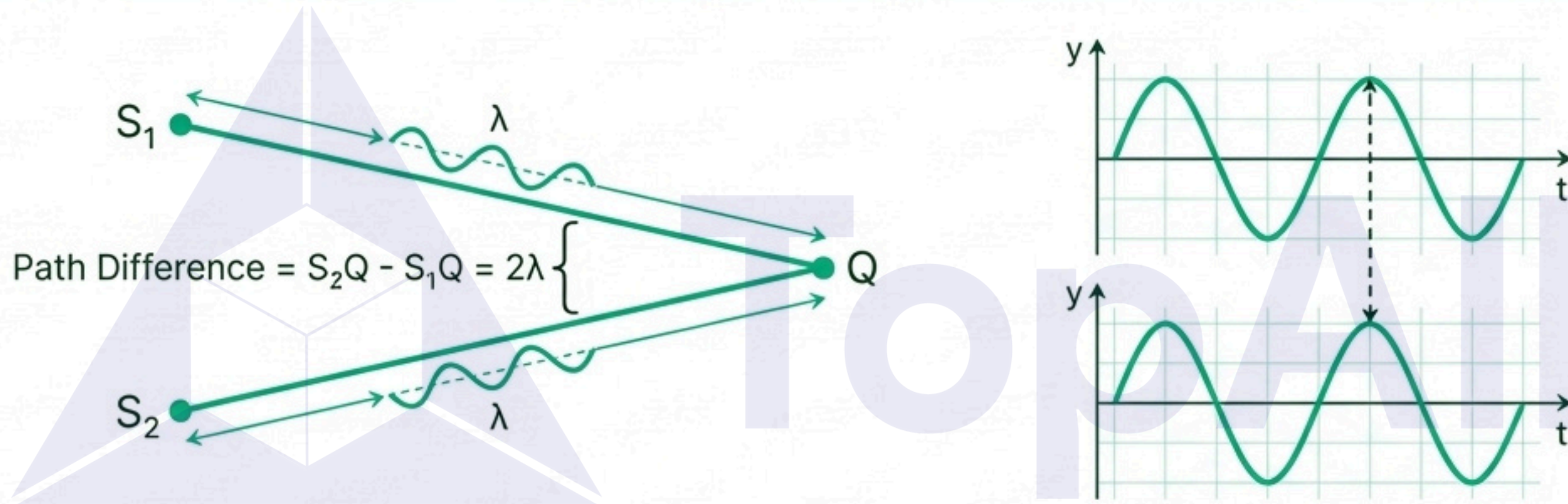
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Constructive Interference (Maxima)

When waves from S_1 and S_2 arrive perfectly in phase, their amplitudes add together to create a maximum displacement.



Condition:

$$\text{Path Difference } S_2Q - S_1Q = n\lambda$$

(where $n = 0, 1, 2, \dots$)

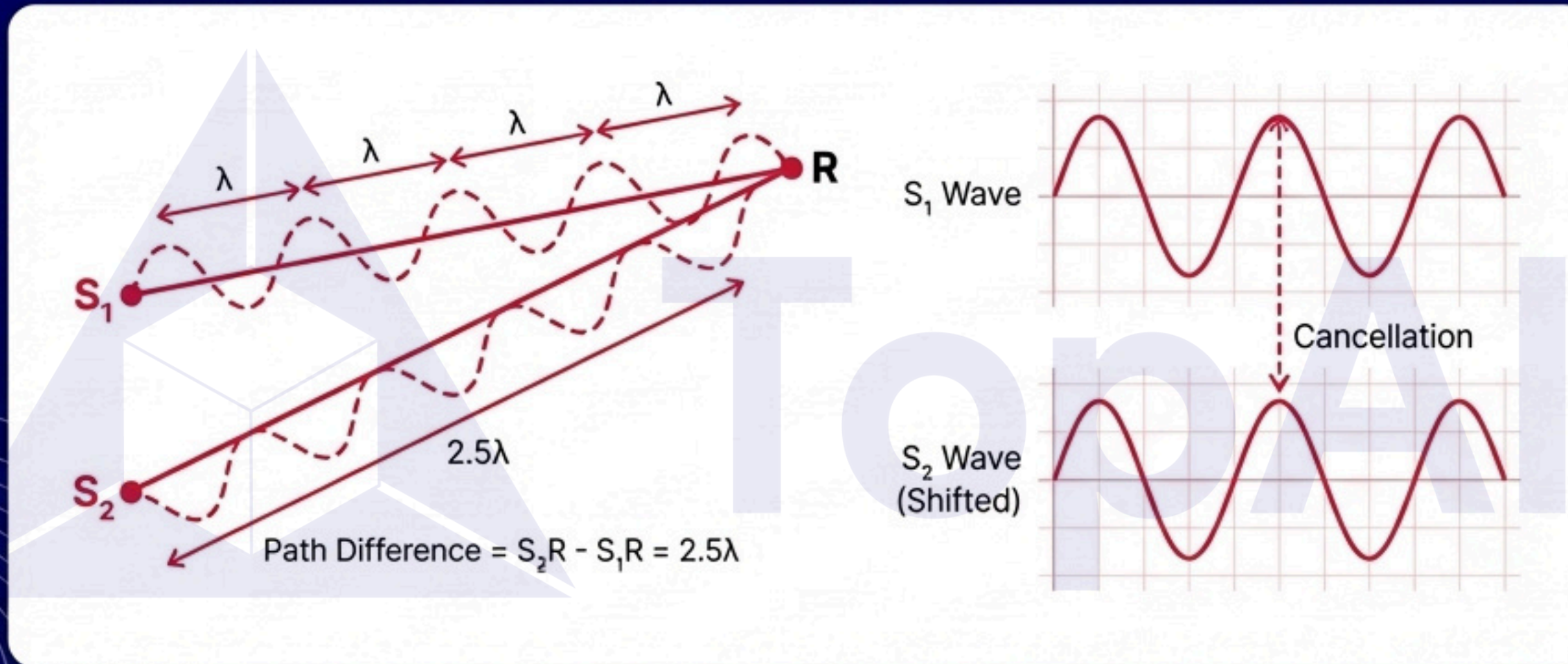
Result:

Resultant Intensity

$$I = 4I_0$$

H1 (White): Destructive Interference (Minima)

Body (White): When waves arrive exactly out of phase (e.g., delayed by a half-cycle), a crest meets a trough, and they perfectly cancel each other out.



Condition: Path Difference
 $S_2R - S_1R = (n + 1/2)\lambda$

Result: Resultant Intensity
 $I = 0$

The General Intensity Formula

For any arbitrary point with a phase difference ϕ between the two displacements y_1 and y_2 , the resultant intensity is governed by a single equation.

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

Notice how $\phi = 0, 2\pi, 4\pi\ldots$ yields $4I_0$ (Constructive).

Notice how $\phi = \pi, 3\pi, 5\pi\ldots$ yields 0 (Destructive).

The Chaos of Incoherent Sources

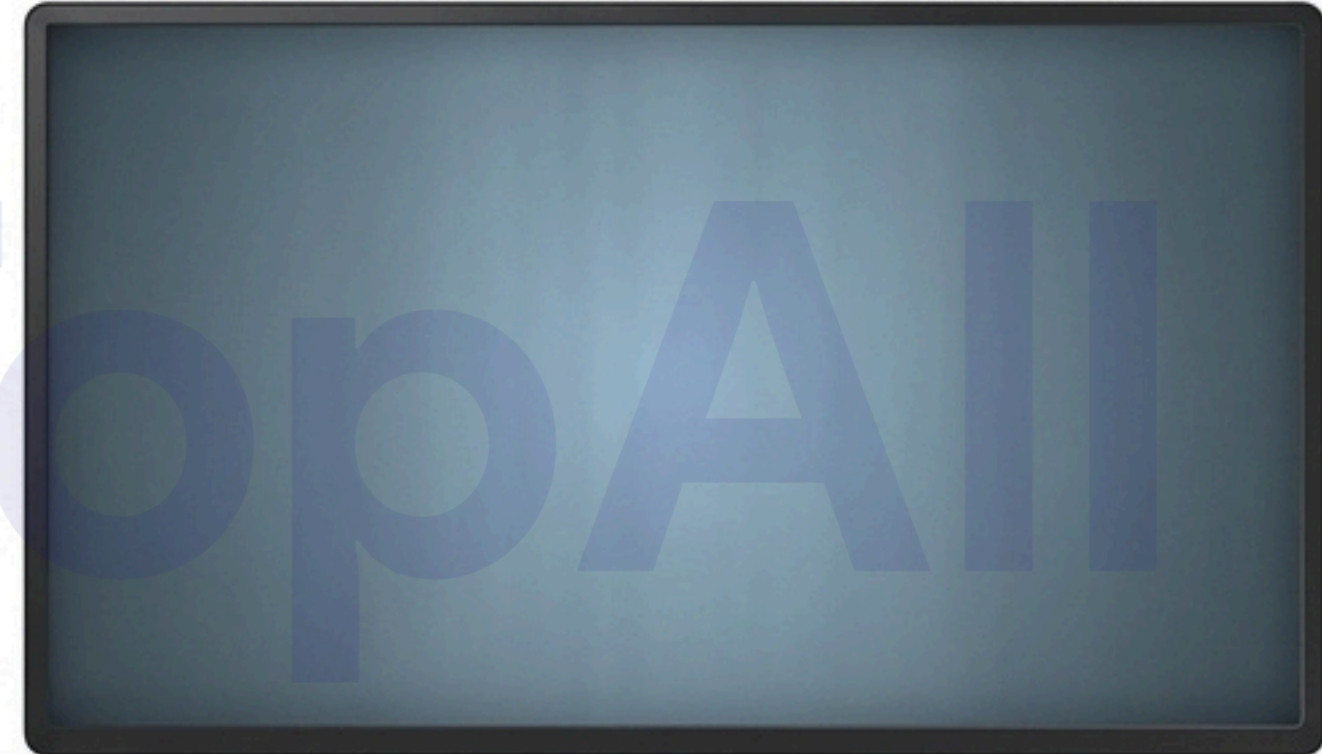


If the needles do not maintain a constant phase difference, the pattern shifts so rapidly that individual maxima and minima cannot be seen.

Coherent Sources



Incoherent Sources



The Time-Averaged Result

The intensities simply add up. Average Intensity $I = 2I_0$. (e.g., Two separate light bulbs illuminating a wall).

Summary & Key Takeaways



	Coherent Sources	Incoherent Sources
Phase Difference	Constant over time	Changes rapidly with time
Intensity Output	Varies predictably between $4I_0$ (Constructive) and 0 (Destructive)	Steady, time-averaged uniform illumination of $2I_0$
Visual Pattern	Stable, observable fringes (maxima/minima)	No steady fringes; rapid blurring.

Understanding this distinction is the key to mastering Wave Optics interference.



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