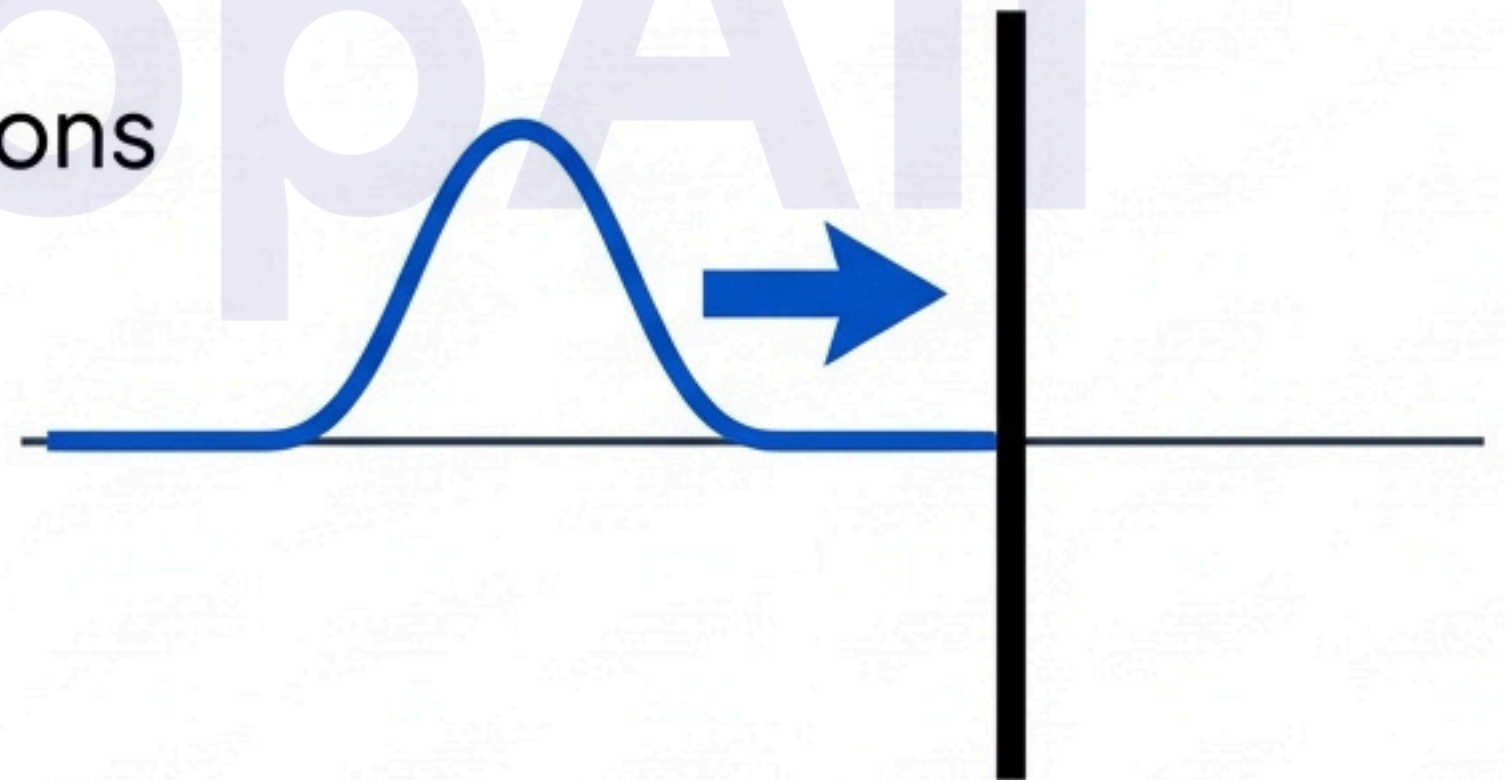


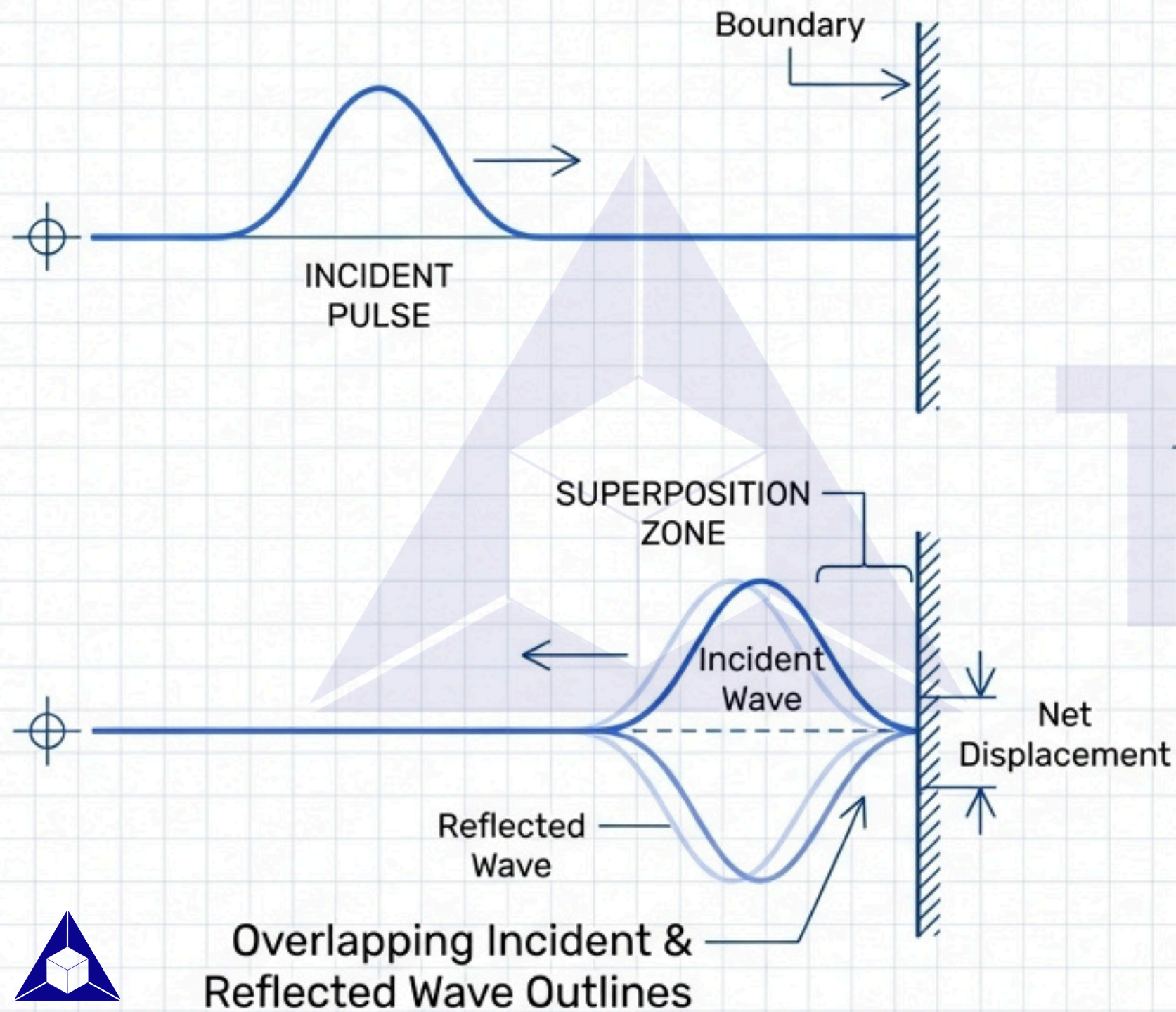
Reflection of Waves

Rigid vs. Open Boundaries

Master the physics of wave reflection, phase reversals, and boundary conditions for your competitive exams.



What Happens at the Boundary?



- When a traveling wave meets a boundary, part or all of the wave is reflected.
- The boundary becomes a point of overlapping disturbances.
- The Golden Rule: The net displacement at the boundary is the algebraic sum of the incident and reflected waves (Principle of Superposition).

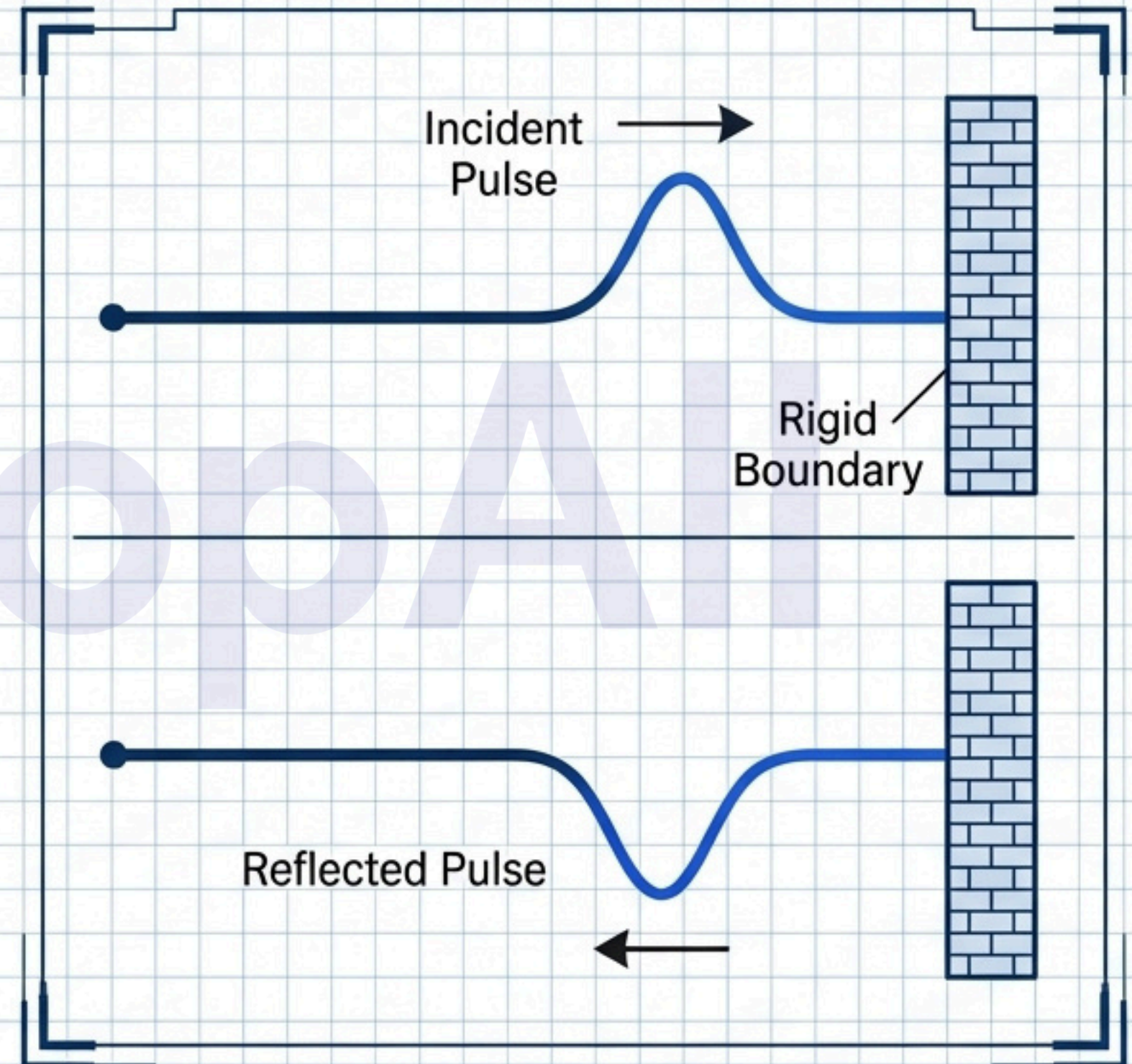
EXAM TIP

The behavior of the reflected wave depends entirely on whether the boundary is fixed (rigid) or free to move (open).

Reflection at a Rigid Boundary

PHASE REVERSAL: π (180°)

- **The Setup:** A pulse travels along a string fixed tightly to a wall.
- **The Physics:** As the pulse pulls up on the wall, Newton's Third Law states the wall pulls down on the string with an equal and opposite force.
- **The Result:** The pulse is inverted. The incident and reflected waves differ by a phase of π to maintain a net zero displacement at the rigid wall at all times.





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Key Highlights

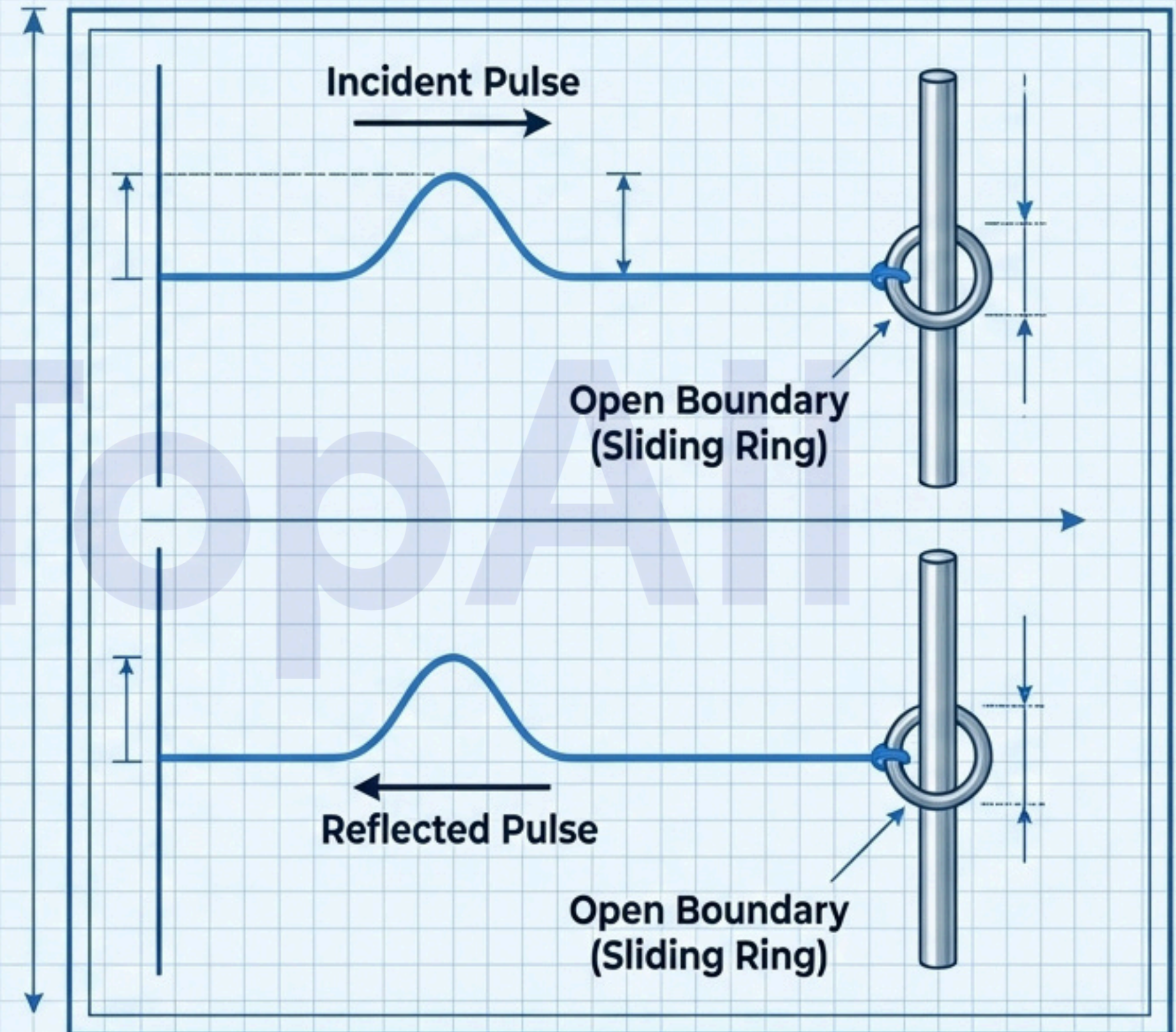
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Reflection at an Open Boundary

NO PHASE REVERSAL: 0

- **The Setup:** A pulse travels along a string tied to a ring that slides freely on a frictionless rod.
- **The Physics:** The ring moves up with the pulse, reaching a maximum height, and then snaps back down, sending the wave back.
- **The Result:** The reflected pulse has the same phase and amplitude as the incident pulse. The net maximum displacement at the boundary is $2a$.



Boundary Conditions: Side-by-Side



Boundary Type	Phase Change ($\Delta\phi$)	Pulse Orientation	Net Displacement at Boundary
Rigid / Closed End	π (180°)	Inverted	0 (Nodes)
Open / Free End	0	Upright (Unchanged)	$2a$ (Antinodes)

The Mathematical Forms



Given an incident traveling wave: $y_i(x,t) = a \sin(kx - \omega t)$

RIGID (PHASE CHANGE $+\pi$)

$$y_r(x, t) = a \sin(kx + \omega t + \pi) = -a \sin(kx + \omega t)$$

OPEN (NO PHASE CHANGE)

$$y_r(x, t) = a \sin(kx + \omega t + 0) = a \sin(kx + \omega t)$$

EXAM TIP

Notice the **sign change** from $(kx - \omega t)$ to $(kx + \omega t)$ —this indicates the mathematical direction of the reflected wave has reversed.

Summary

1. Rigid boundaries flip the wave (Phase reversal of π). The displacement at the boundary is always zero.
2. Open boundaries return the wave upright (Phase reversal of 0). The displacement at the boundary is doubled ($2a$).
3. The mathematical direction of the reflected wave always reverses (e.g., from $-\omega t$ to $+\omega t$).

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