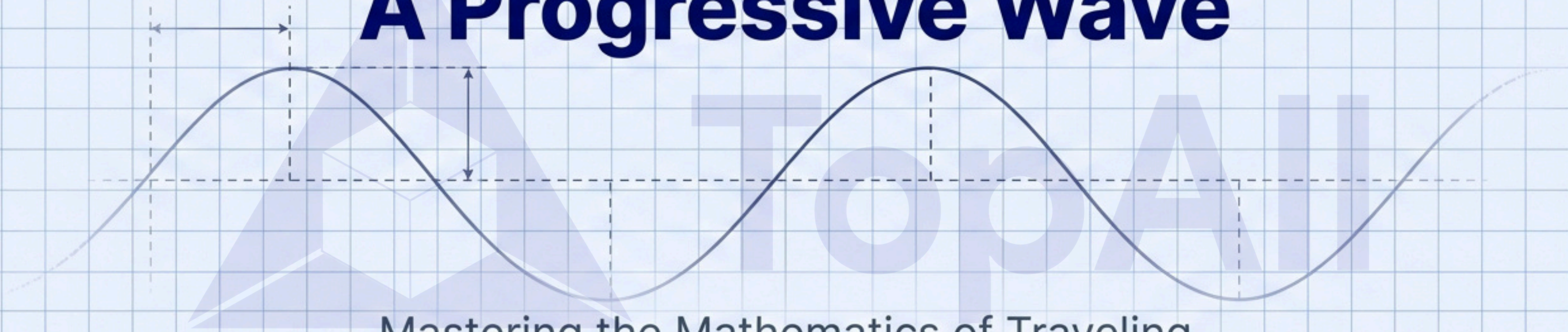


Displacement Relation In A Progressive Wave

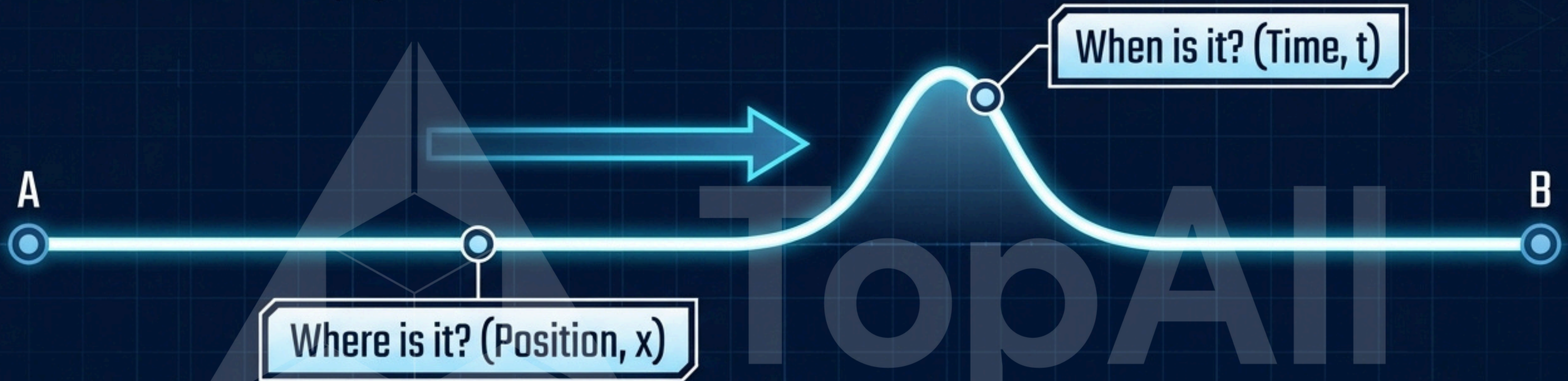


Mastering the Mathematics of Traveling
Waves for NEET/JEE

Core Concept

DEFINING THE PROGRESSIVE WAVE

A progressive (or traveling) wave is a disturbance that moves from one part of a medium to another without the physical transfer of matter.



- To describe it mathematically, we need a function of both position (x) and time (t).
- At any instant, the function gives the shape of the wave.
- At any location, it describes the motion of the particle.

$$y(x,t) = \text{Shape} + \text{Motion}$$

THE MASTER EQUATION FOR A TRAVELING WAVE



For a transverse sinusoidal wave traveling in the positive x-direction, the displacement y from equilibrium is:

Amplitude

Eq. 14.2

$$y(x, t) = a \sin(kx - \omega t + \phi)$$

Displacement

Phase of the wave

Linear Combination Form (Eq. 14.3): $y(x, t) = A \sin(kx - \omega t) + B \cos(kx - \omega t)$

Where: $a = \sqrt{A^2 + B^2} \mid \tan(\phi) = \frac{B}{A}$



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Decoding The Standard Symbols

a (Amplitude)

Maximum displacement of the medium's constituents from equilibrium. Always a positive constant.

ϕ (Initial Phase Angle)

The phase at $x = 0$ and $t = 0$. Can be set to zero by choosing a suitable origin.

k (Angular Wave Number)

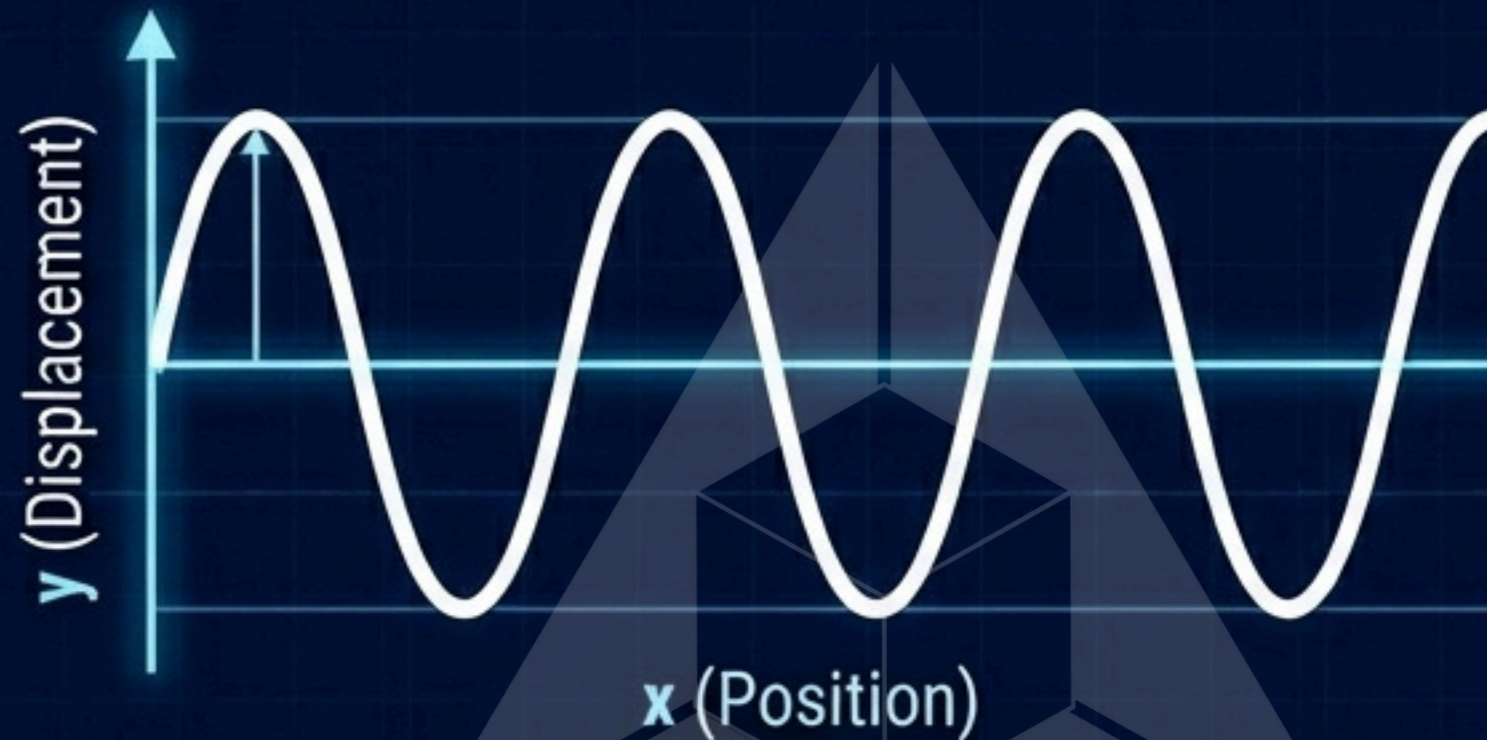
Propagation constant.
 $k = 2\pi / \lambda$. (SI Unit: rad m^{-1})

ω (Angular Frequency)

Determines the period of the wave.
 $\omega = 2\pi / T$. (SI Unit: rad s^{-1})

Space vs. Time: Two Ways To Look At A Wave

1. Fix Time ($t = t_0$)



- **Concept:** A snapshot of the wave in space.
- **Phase Argument:** ($kx - \text{constant}$)
- **Result:** The shape of the wave is a sine function of x . You see the whole wave at one single instant.

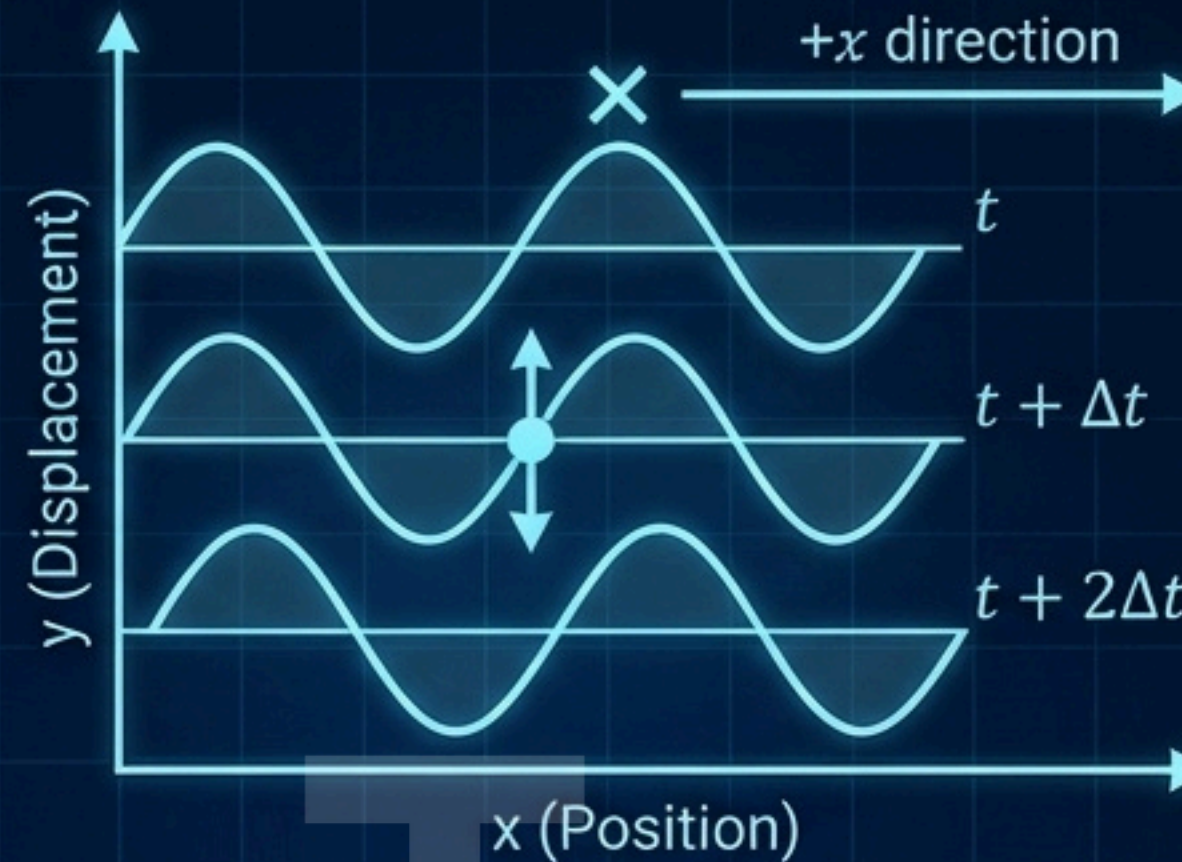
2. Fix Position ($x = x_0$)



- **Concept:** Watching a single particle over time.
- **Phase Argument:** ($\text{constant} - \omega t$)
- **Result:** Displacement varies sinusoidally with time. The isolated particle executes Simple Harmonic Motion (SHM).

FIGURE 14.6 & EQUATION 14.4

Tracking Wave Progression & Direction



As the wave progresses, the crest moves forward, but the particle at the origin simply oscillates about its mean position.

Right-Traveling Wave
(Positive x-axis)

$$y(x, t) = a \sin(kx - \omega t + \phi) \quad \text{Eq. 14.2}$$

Left-Traveling Wave
(Negative x-axis)

$$y(x, t) = a \sin(kx + \omega t + \phi) \quad \text{Eq. 14.4}$$

Chapter Insights



KEY TAKEAWAYS

- ✓ A progressive wave requires a mathematical function of both position (x) and time (t).
- ✓ The standard equation $y(x, t) = a \sin(kx - \omega t)$ describes a wave moving in the $+x$ direction.
- ✓ Fixing time t gives the wave's shape in space; fixing position x gives the particle's SHM in time.
- ✓ A positive sign inside the phase argument ($kx + \omega t$) reverses the wave's travel direction to $-x$.

EXAM TIP

Pay close attention to the negative or positive sign between kx and ωt —it is a quick trick for solving multiple-choice wave direction questions!

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