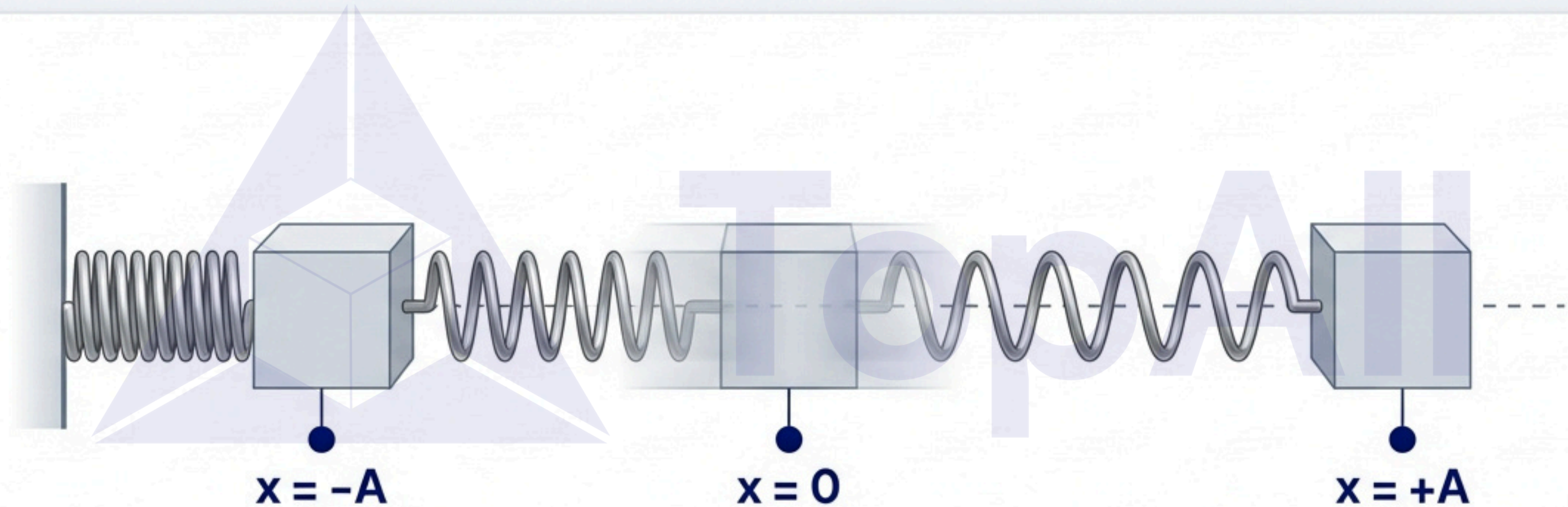


Velocity and Acceleration in SHM

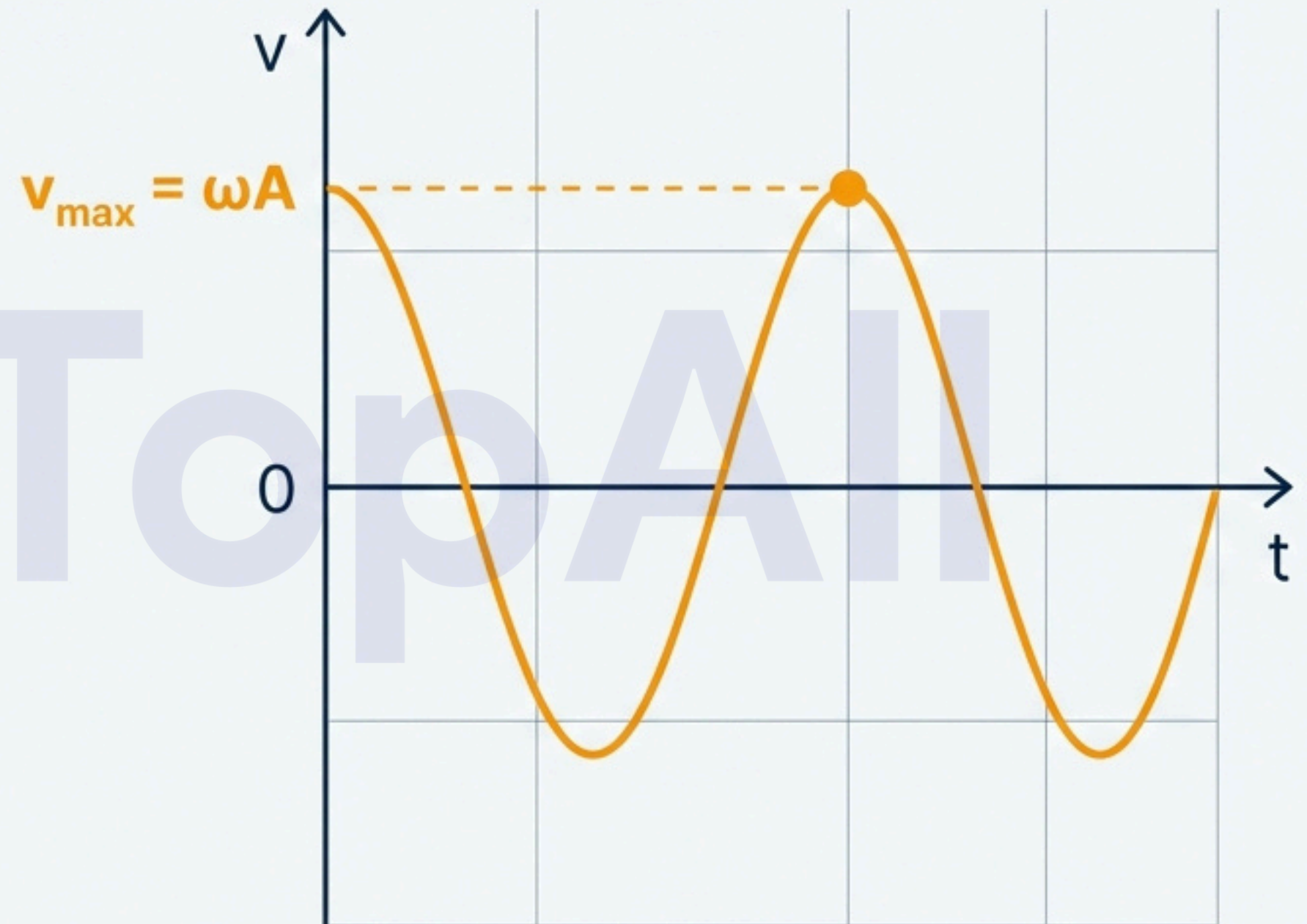
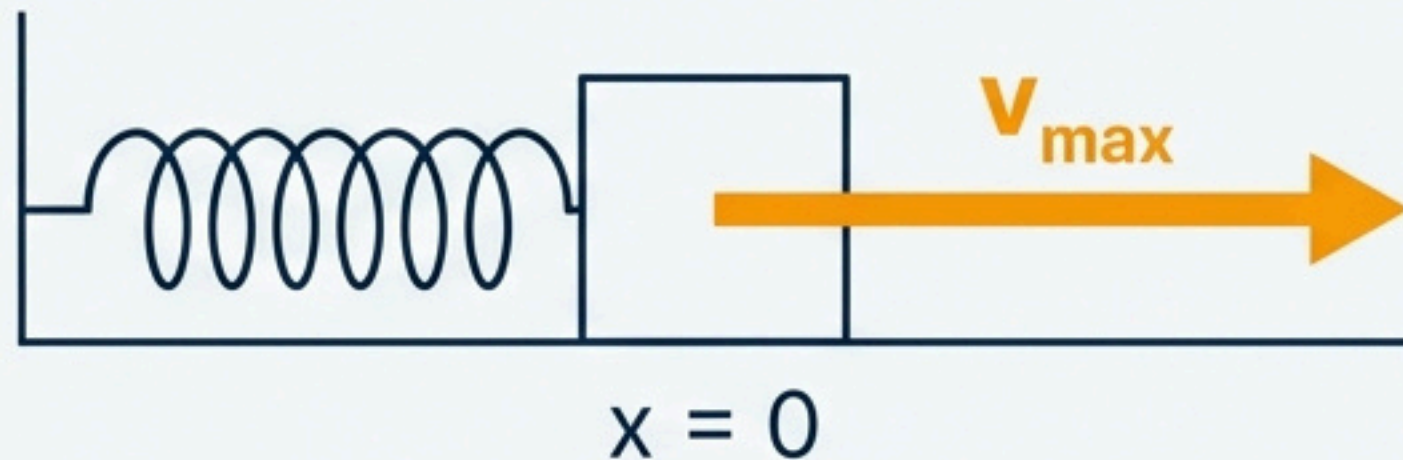
Why speed is maximum at the center, and zero at the extremes.



Velocity in SHM

$$v(t) = -\omega A \sin(\omega t + \phi)$$

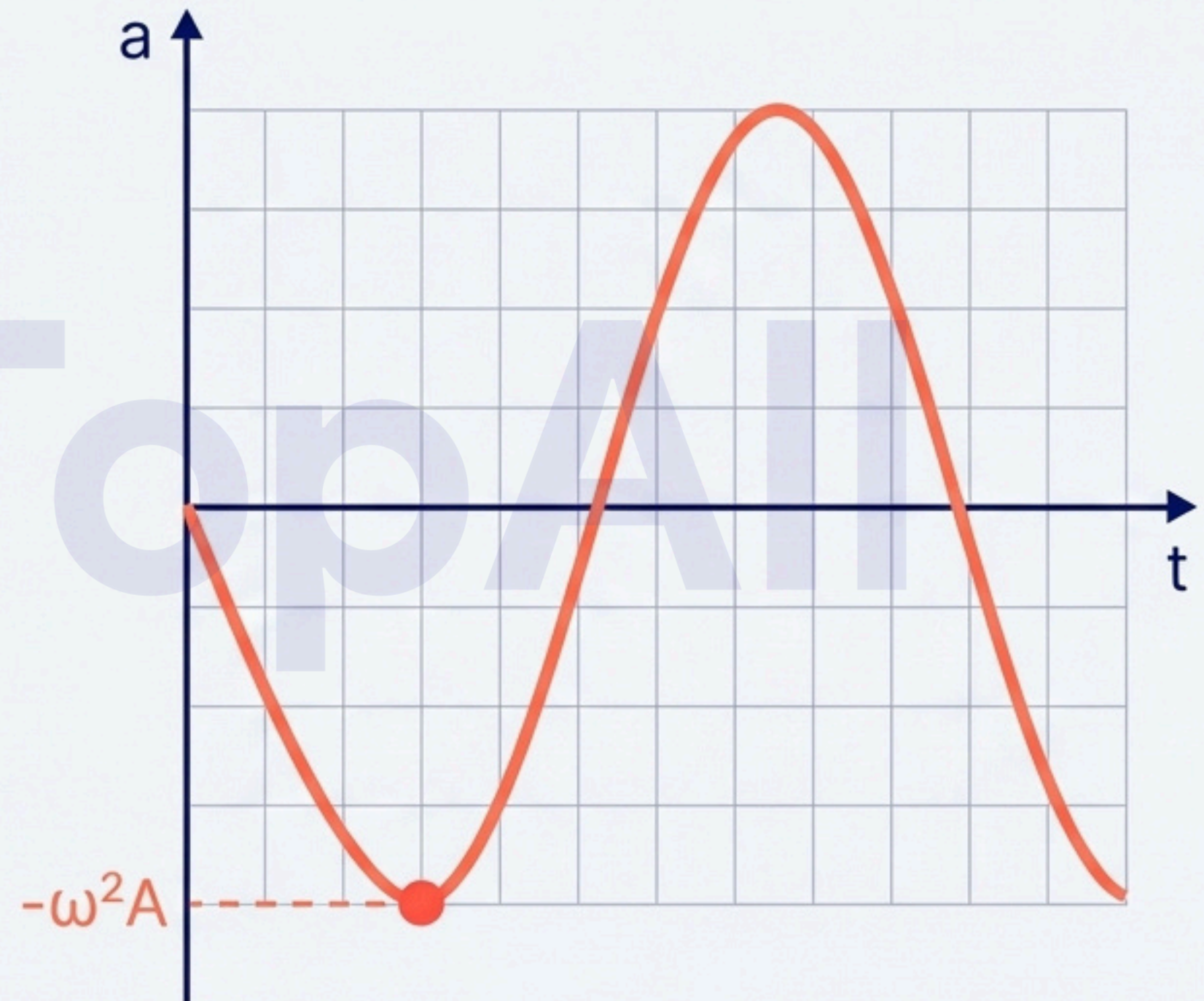
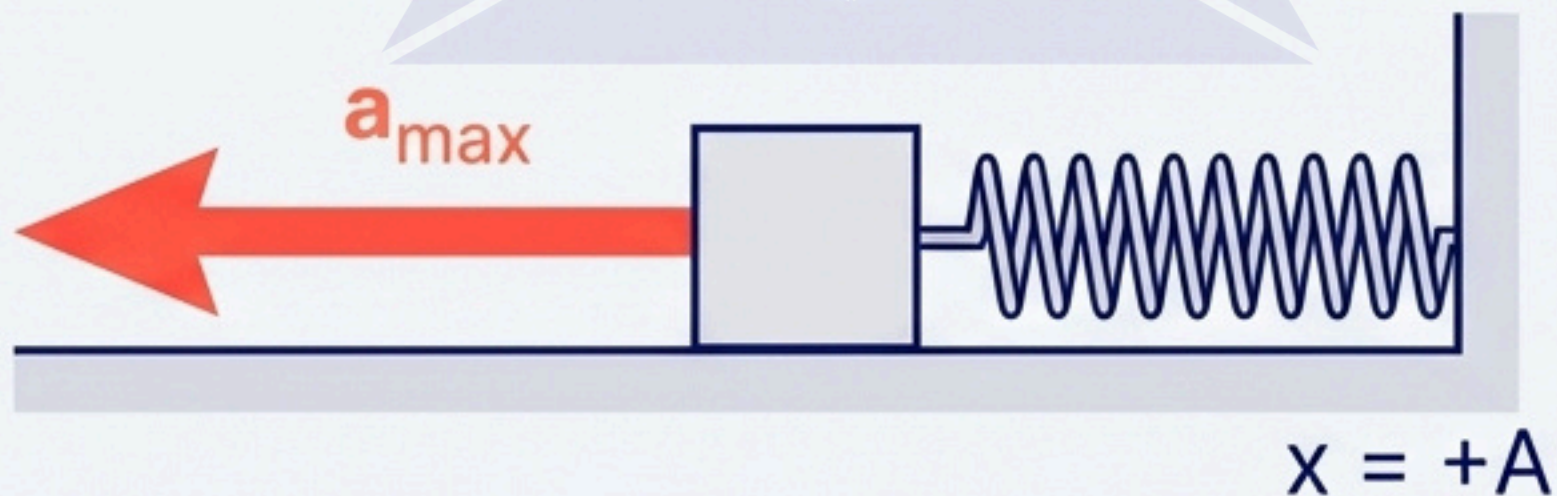
Velocity is maximum at the mean position and zero at the extremes.



Acceleration in SHM

$$\mathbf{a}(t) = -\omega^2 A \cos(\omega t + \phi) = -\omega^2 \mathbf{x}(t)$$

Insight: The negative sign dictates a restoring nature—acceleration always points back toward the center.





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Key Highlights

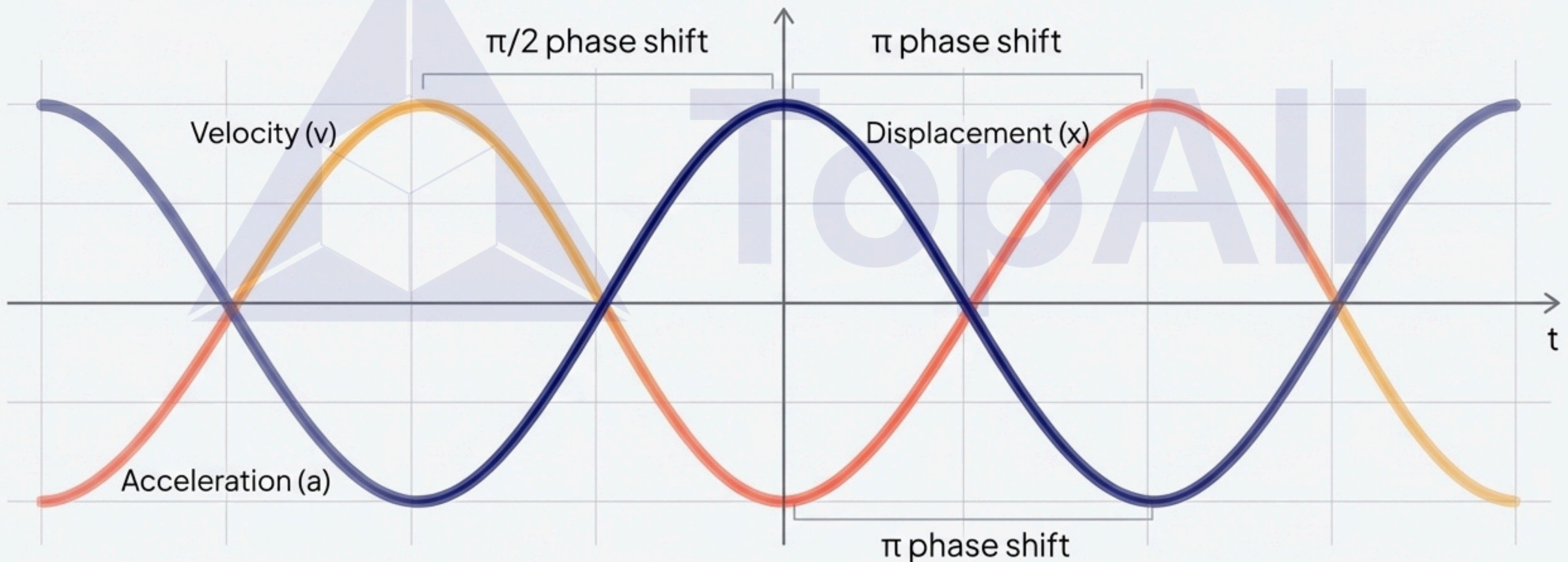
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The Phase Difference

Velocity leads by $\pi/2$

Acceleration opposes by π



Extreme vs. Mean Position

At Mean Position ($x = 0$)



Velocity: **Maximum** ($\pm \omega A$)

Acceleration: **Zero**

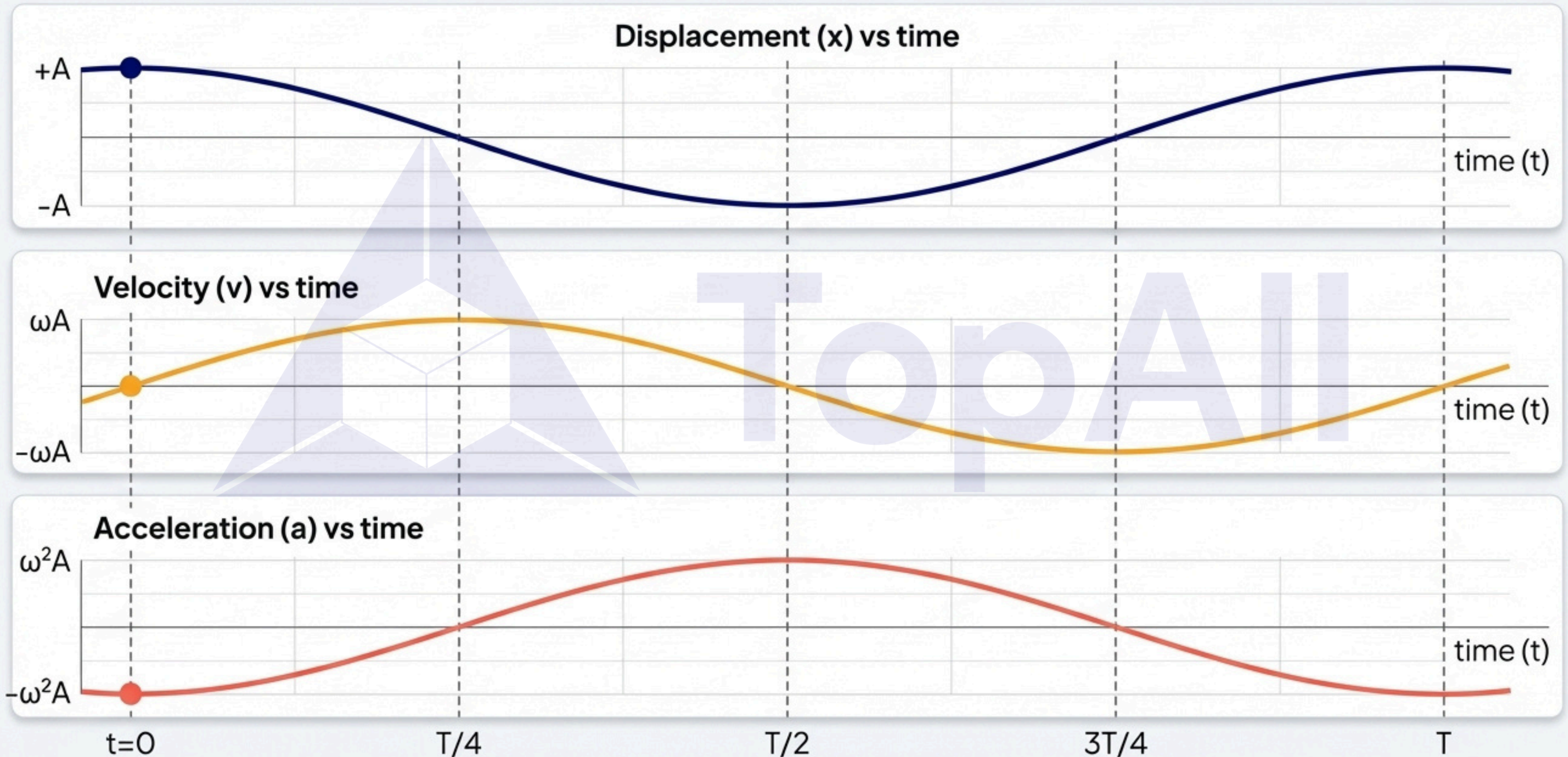
At Extreme Position ($x = \pm A$)



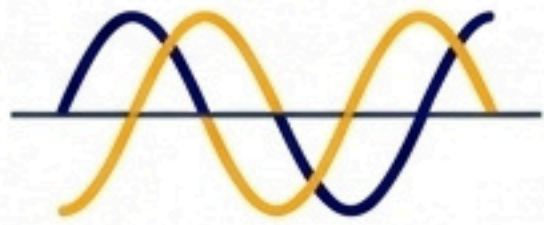
Velocity: **Zero**

Acceleration: **Maximum** ($\mp \omega^2 A$)

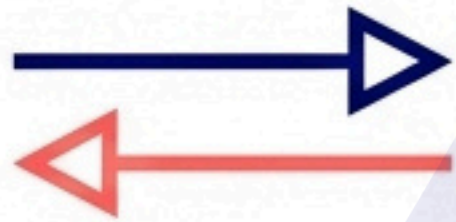
Graphing the Complete Cycle (assuming $\phi=0$)



Key Takeaways



Velocity and displacement always differ by a $\pi/2$ phase shift.



Acceleration is always strictly opposite to displacement.

$$\mathbf{a} = -\omega^2 \mathbf{x}$$

The defining dynamic relation of all Simple Harmonic Motion.



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