

2.4 Kinematic Equations for Uniformly Accelerated Motion



The Kinematic Toolkit: Five Core Variables

x

Displacement

t

Time taken

v_0

Initial velocity
(at $t = 0$)

v

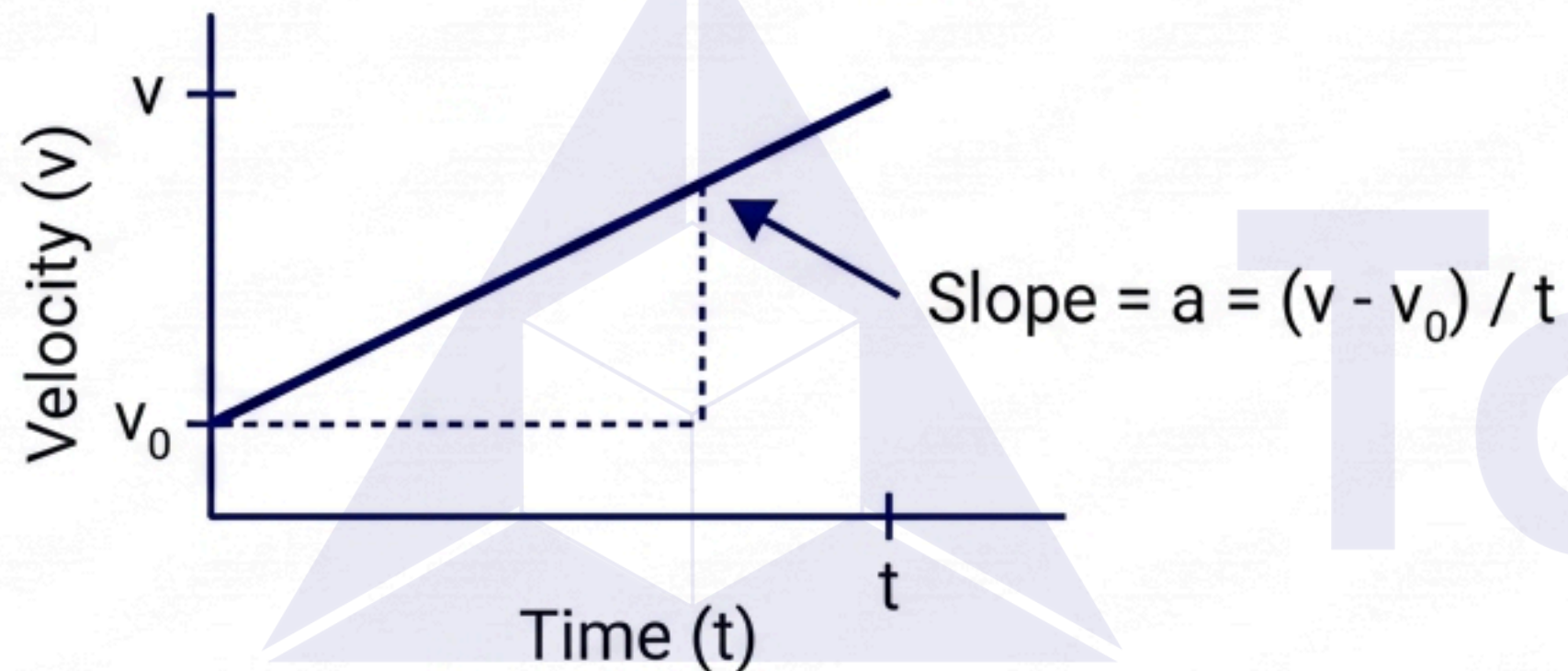
Final velocity

a

Constant
acceleration

The First Equation of Motion

Velocity-Time Graph



Algebraic Derivation

Step 1:

$$a = (v - v_0) / t$$

Step 2:

$$at = v - v_0$$

$$v = v_0 + at$$

Velocity at any time t equals the starting velocity plus the velocity gained from acceleration.



You've Learned the Theory. Let's Test Them Now.

$$E=mc^2$$



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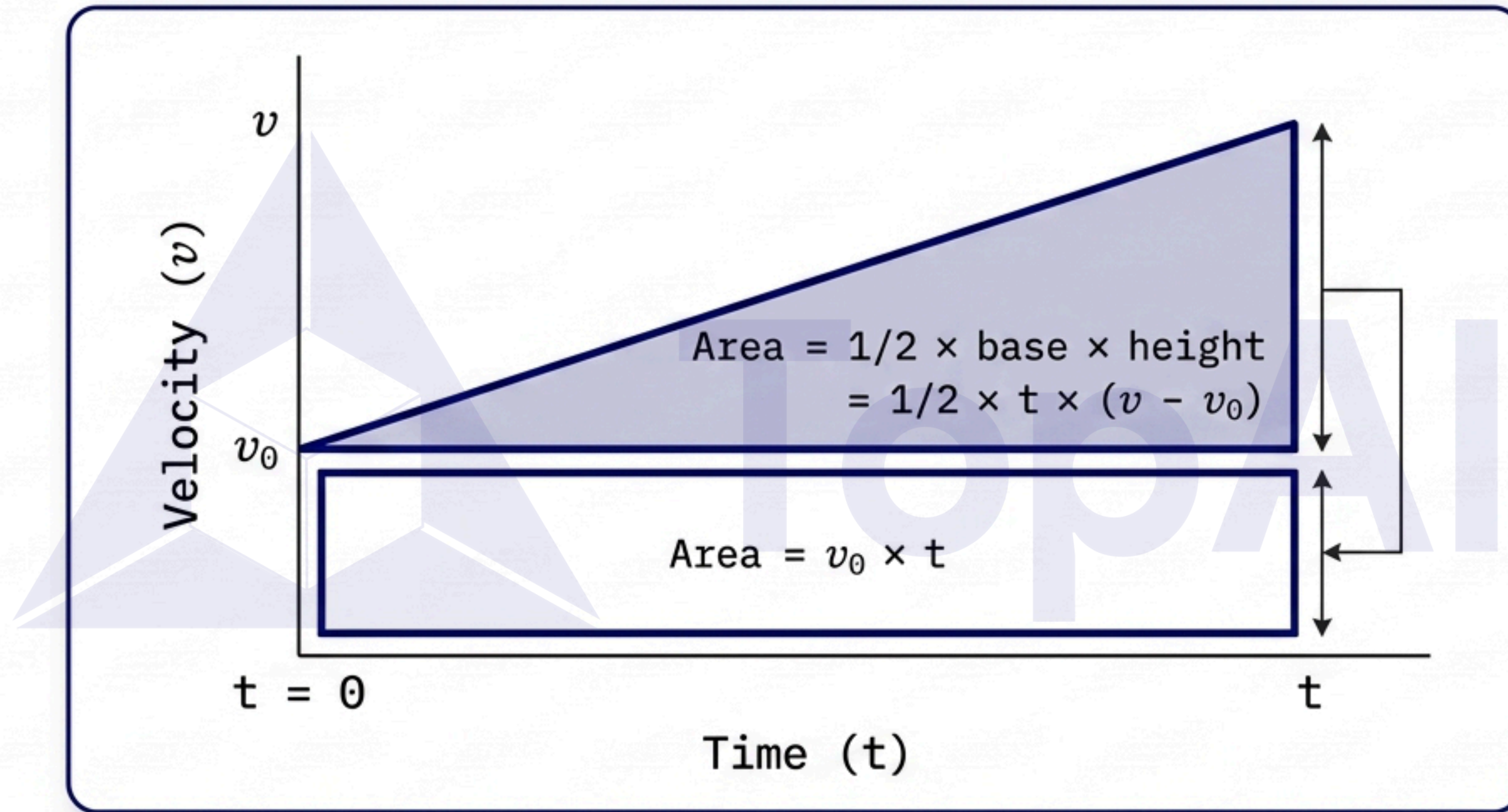
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Key Highlights

- » Free Study Material, Videos & Infographics
- » Push Your Limits with Level-Based Challenges
- » Climb the Leaderboard Among Fellow Aspirants
- » Practice Unlimited MCQs for NEET & JEE
- » Get Clear Explanations, Not Just Marks
- » Track Your Performance Smarter



Deriving Displacement from the $v-t$ Curve



$$\text{Displacement (x)} = [\text{Rectangle Area}] + [\text{Triangle Area}]$$

The Second Equation of Motion



Step 1: Geometry

$$x = v_0 t + 1/2 t (v - v_0)$$



Step 2: Substitution

$$x = v_0 t + 1/2 t (v - v_0)$$

From First Eq:
 $(v - v_0) = at$



Step 3: Integration

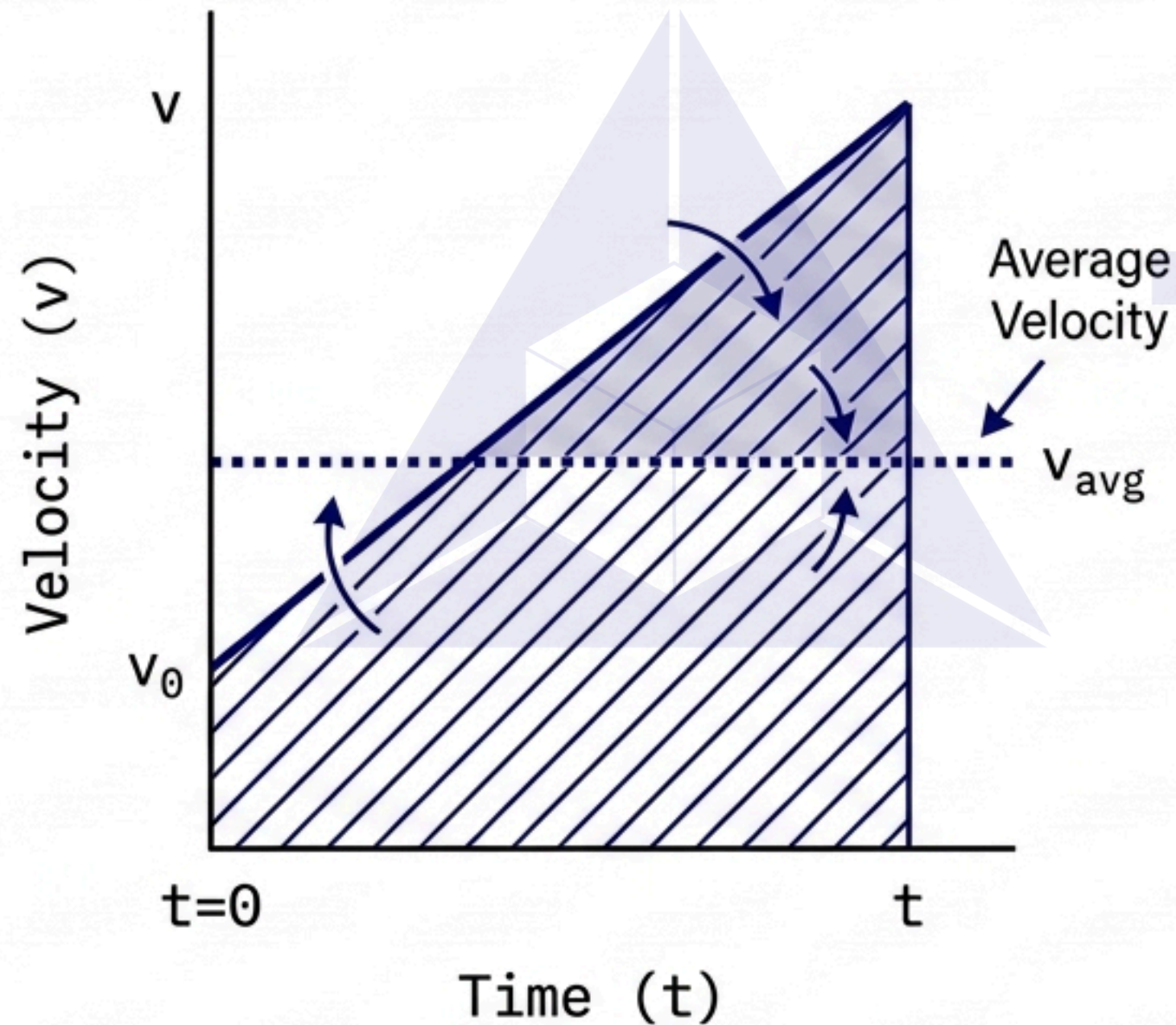
Substitute at into the triangle area calculation to get $1/2 t (at)$



$$x = v_0 t + 1/2 at^2$$

Displacement equals the distance covered without acceleration ($v_0 t$) plus the extra distance generated by accelerating ($1/2 at^2$).

The Average Velocity Form



When acceleration is constant, displacement is equivalent to traveling at the arithmetic average of the initial and final velocities.

$$\text{Average Velocity } (v_{avg}) = \frac{v_0 + v}{2}$$

$$x = \left(\frac{v_0 + v}{2} \right) t$$

Diagnostic: Use when acceleration (a) is unknown.

The Third Equation of Motion

Isolate t

From $v = v_0 + at$,
extract time:

$$t = \frac{v - v_0}{a}$$

Substitute

Plug t into the Average
Velocity form:

$$x = \left[\frac{v_0 + v}{2} \right] \times \left[\frac{v - v_0}{a} \right]$$

Multiply

Resolve the difference
of squares:

$$x = \frac{v^2 - v_0^2}{2a}$$

Diagnostic: Use when
time (t) is unknown.

$$v^2 = v_0^2 + 2ax$$

The Complete Kinematic Toolkit



$$v = v_0 + at$$

Missing Variable: x (Displacement)

$$x = v_0 t + \frac{1}{2} at^2$$

Missing Variable: v (Final Velocity)

$$v^2 = v_0^2 + 2ax$$

Missing Variable: t (Time)

What if we don't start at zero?

If initial position at $t=0$ is x_0 , simply replace x with $(x - x_0)$.

$$x = x_0 + v_0 t + \frac{1}{2} at^2$$



You've Learned the Theory.

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