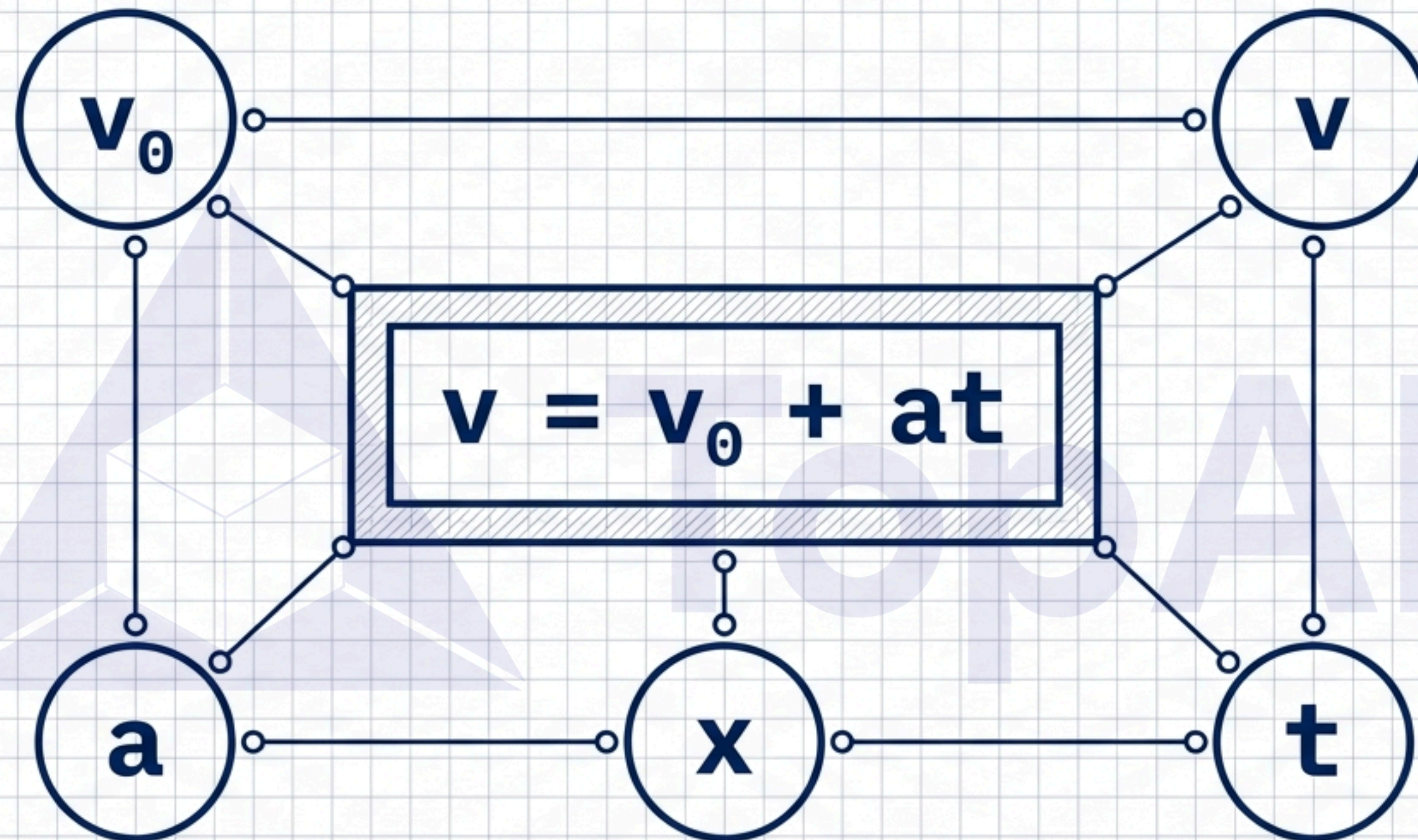


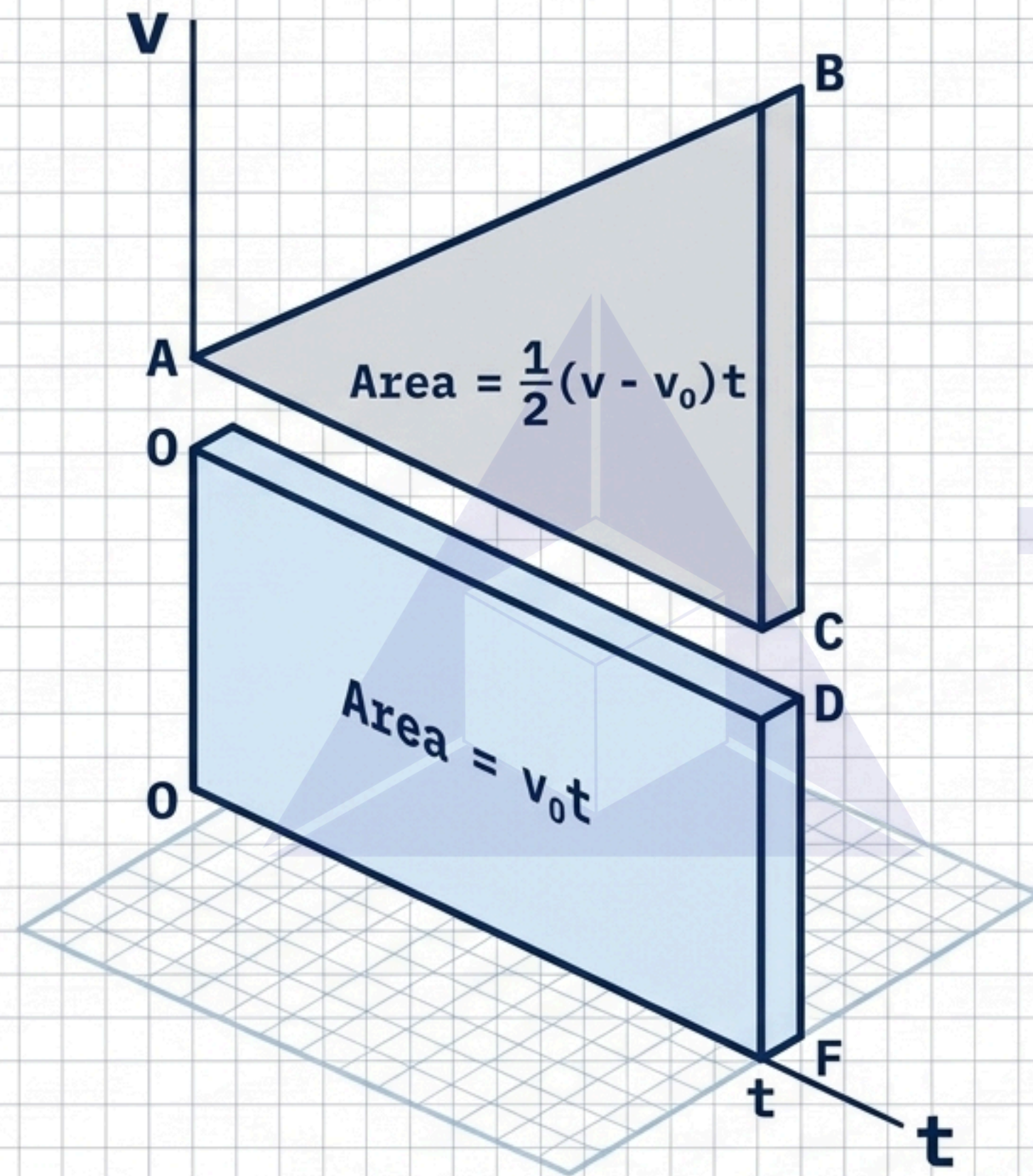
Motion in a Straight Line · Concept 3

Kinematic Equations for Uniformly Accelerated Motion — Derivation

Two Tracks to Truth: Graphical Geometry
and Analytical Calculus.



These five variables can only be linked by simple kinematic equations if, and only if, the acceleration (a) remains strictly constant.



Displacement (x) =
Area of Rectangle
+
Area of Triangle



$$x = v_0 t + \frac{1}{2}(v - v_0)t$$

$$x = v_0 t + \frac{1}{2}(v - v_0)t$$

Substitution →

$$\text{Since } v = v_0 + at, \text{ then } (v - v_0) = at$$



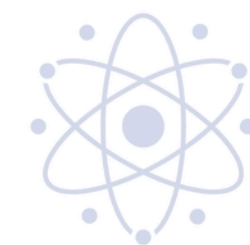
$$x = v_0 t + \frac{1}{2}at^2$$

By substituting the acceleration constraint into the geometric area, we derive the exact parabolic displacement formula.



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

$$E=mc^2$$



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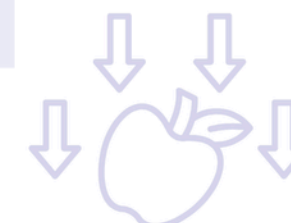
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Calculus Derivation: Velocity (Example 2.2)

$$a = dv/dt \rightarrow dv = a dt$$

$$\int dv = \int a dt$$

$$\int_{v_0}^v dv = a \int_0^t dt$$

Note: 'a' is pulled outside the integral because it is constant.

$$v - v_0 = at$$

$$\mathbf{v = v_0 + at}$$

Calculus Derivation: Displacement (Example 2.2)

$$v = dx/dt \rightarrow dx = v dt$$

$$dx = (v_0 + at) dt$$

$$\int dx = \int (v_0 + at) dt$$

$$\int_{x_0}^x dx = \int_0^t (v_0 + at) dt$$

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

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

Calculus Derivation: Velocity-Position (Example 2.2)

$$a = dv/dt = (dv/dx) * (dx/dt) = v(dv/dx)$$

$$v \, dv = a \, dx$$

$$\int_{v_0}^v v \, dv = a \int_{x_0}^x dx$$

$$(v^2 - v_0^2)/2 = a(x - x_0)$$

$$v^2 - v_0^2 = 2a(x - x_0)$$

Standard Forms

Assuming initial position $x_0 = 0$

$$v = v_0 + at$$

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

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

General Forms

Assuming non-zero initial position $x_0 \neq 0$

$$v = v_0 + at$$

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

$$v^2 = v_0^2 + 2a(x - x_0)$$



TRAP ALERT

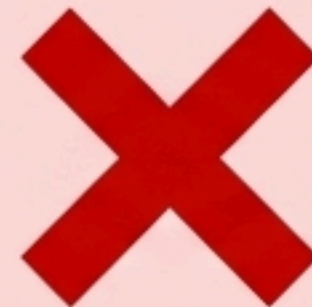
These equations hold ONLY for constant acceleration — unlike the always-true instantaneous definitions $v=dx/dt$ and $a=dv/dt$. Every quantity is algebraic: substitute with correct signs.



$a = \text{constant}$



Kinematic
Equations
Valid



$a = \text{variable}$



~~Kinematic
Equations
Invalid~~

✓ Key Takeaways

Same three equations from area-under-curve or calculus — valid strictly under constant acceleration, with every sign applied correctly.

$$\mathbf{v = v_0 + at} \quad | \quad \mathbf{x = v_0t + (1/2)at^2} \quad | \quad \mathbf{v^2 = v_0^2 + 2ax}$$



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