

Motion in a Plane · Concept 7

Motion in a Plane with Constant Acceleration

Mastering 2D Kinematics and the
Independence of Motion

The 2D Kinematic Framework

General equations for velocity and position over time interval t :

$$\mathbf{v} = \mathbf{v}_0 + \mathbf{a}^*t$$
$$\mathbf{r} = \mathbf{r}_0 + \mathbf{v}_0t + (1/2)\mathbf{a}t^2$$

X-Axis Components

Horizontal motion variables.

$$v_x = v_{ox} + a_x t$$
$$x = x_o + v_{ox}t + (1/2)a_x t^2$$

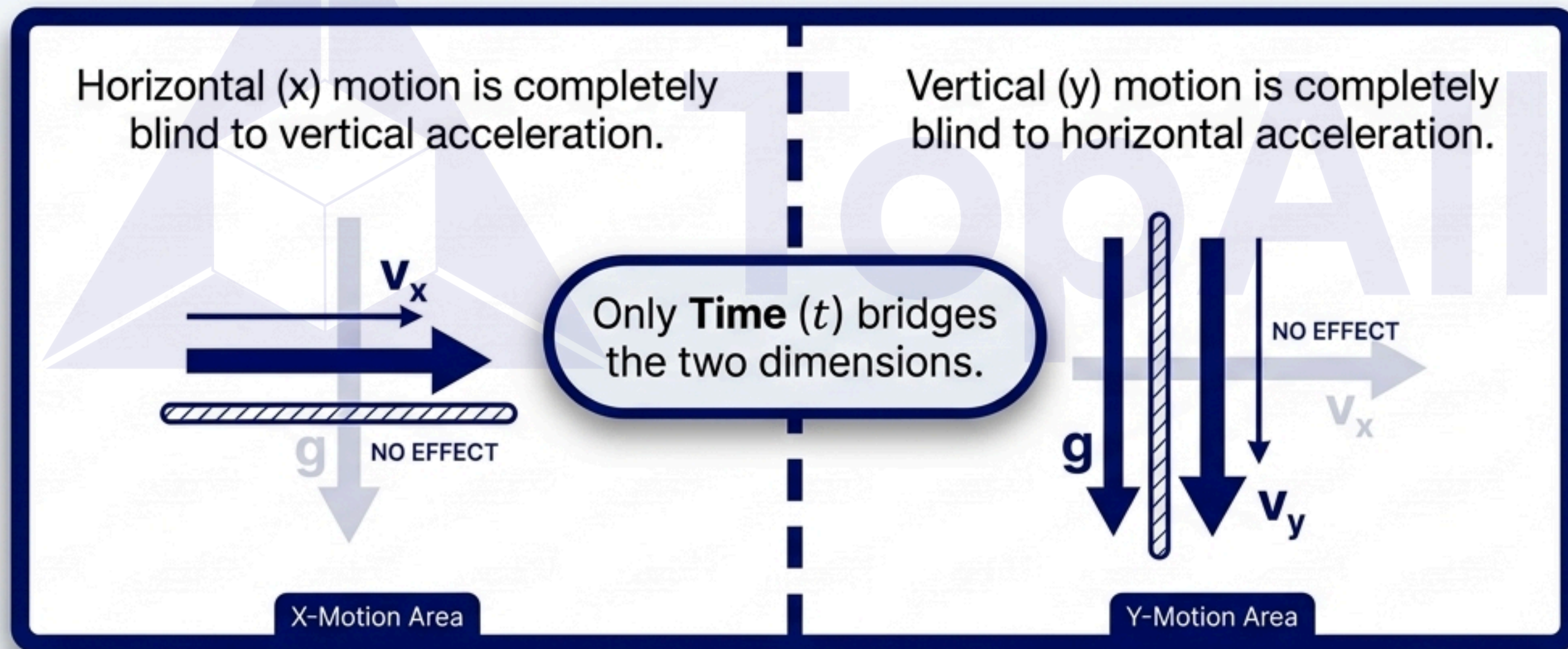
Y-Axis Components

Vertical motion variables.

$$v_y = v_{oy} + a_y t$$
$$y = y_o + v_{oy}t + (1/2)a_y t^2$$

The Core Principle: Independence of Motion

Motion in a plane (two-dimensions) can be treated as two separate, simultaneous one-dimensional motions with constant acceleration along two perpendicular directions.





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$$E=mc^2$$



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Exam Application · Example 3.5

A particle starts from the origin at $t = 0$ with a velocity of $\mathbf{v} = 5.0 \hat{\mathbf{i}} \text{ m/s}$ and moves in the x-y plane with a constant acceleration of $\mathbf{a} = (3.0 \hat{\mathbf{i}} + 2.0 \hat{\mathbf{j}}) \text{ m/s}^2$.

What is the speed of the particle at the instant its x-coordinate is $x = 84 \text{ m}$?

[A] 14.0 m/s

[B] 26.0 m/s

[C] 36.0 m/s

[D] 84.0 m/s

Solution Reveal Panel



Step 1 (Extract Position Eq): $\mathbf{r}(t) = (5.0t + 1.5t^2)\hat{\mathbf{i}} + (1.0t^2)\hat{\mathbf{j}}$

Step 2 (Solve known dimension for t): $x(t) = 5.0t + 1.5t^2 = 84 \rightarrow t = 6 \text{ s}$

Step 3 (Find velocity components at $t=6$): $\mathbf{v}(t) = (5.0 + 3.0t)\hat{\mathbf{i}} + (2.0t)\hat{\mathbf{j}} \rightarrow \mathbf{v}(6) = 23.0\hat{\mathbf{i}} + 12.0\hat{\mathbf{j}}$

Step 4 (Calculate Speed): $|\vec{\mathbf{v}}| = \sqrt{23.0^2 + 12.0^2} \approx 26 \text{ m/s}$

EXAM TRAP ALERT



Solve the coordinate equation you have data for FIRST, then substitute that t into the other — don't solve both simultaneously.



Pro-tip: Students often get paralyzed trying to construct a single complex 2D equation. Isolate the axis with knowns (like $x = 84$ m), extract time (t), and plug that time into your target equation. Treat t as your passport between the x and y axes.

✓ CONCEPT 7 WRAP-UP

Under constant acceleration, x- and y-motions are fully independent — exploit that to solve for t in one coordinate first.

- » • 2D kinematics is just 1D kinematics performed twice.
- » • Vectors $\mathbf{v}$ and $\mathbf{r}$ decompose cleanly into their scalar x and y components.
- » • Time (t) is the only scalar that transfers between axes.



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