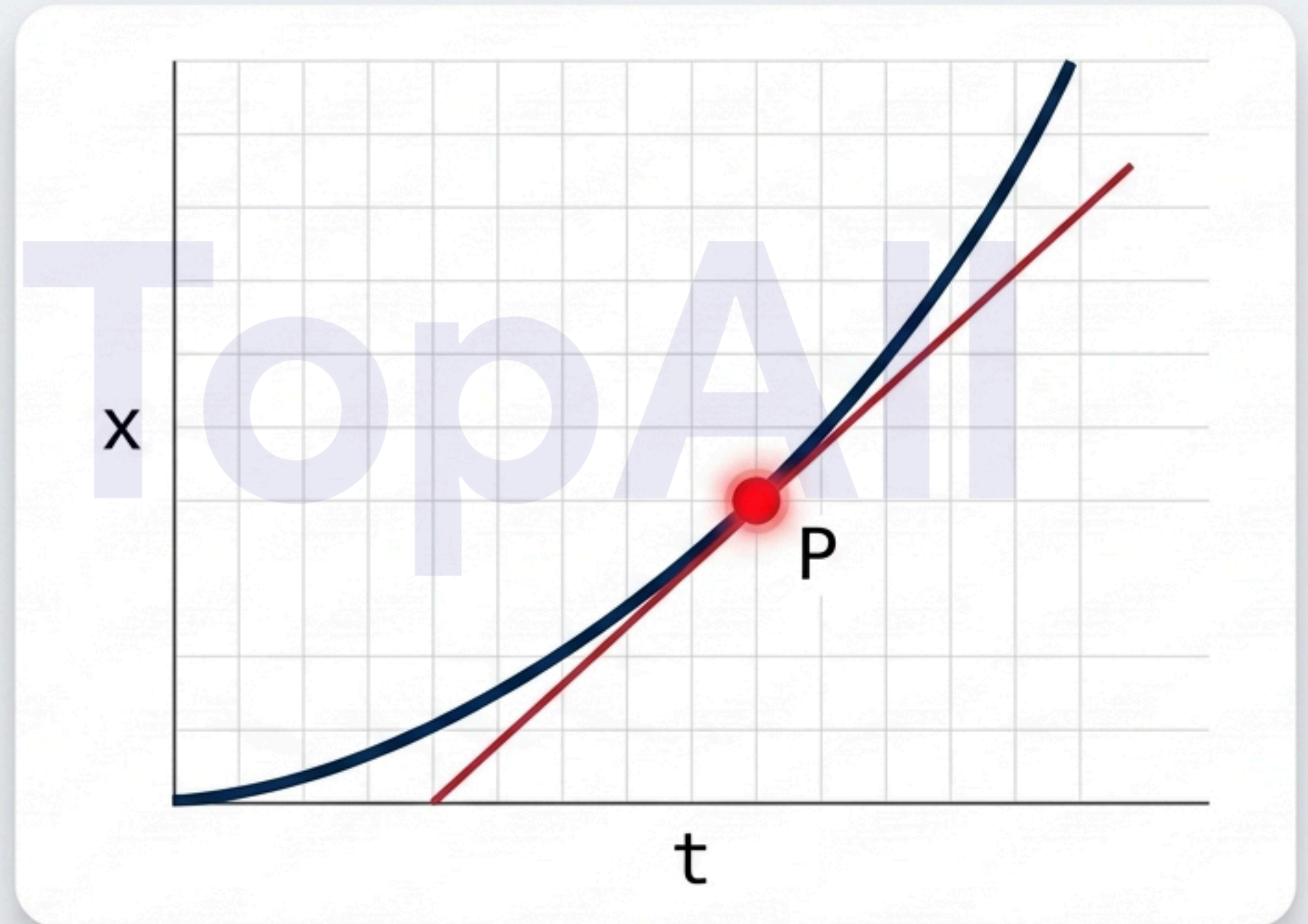


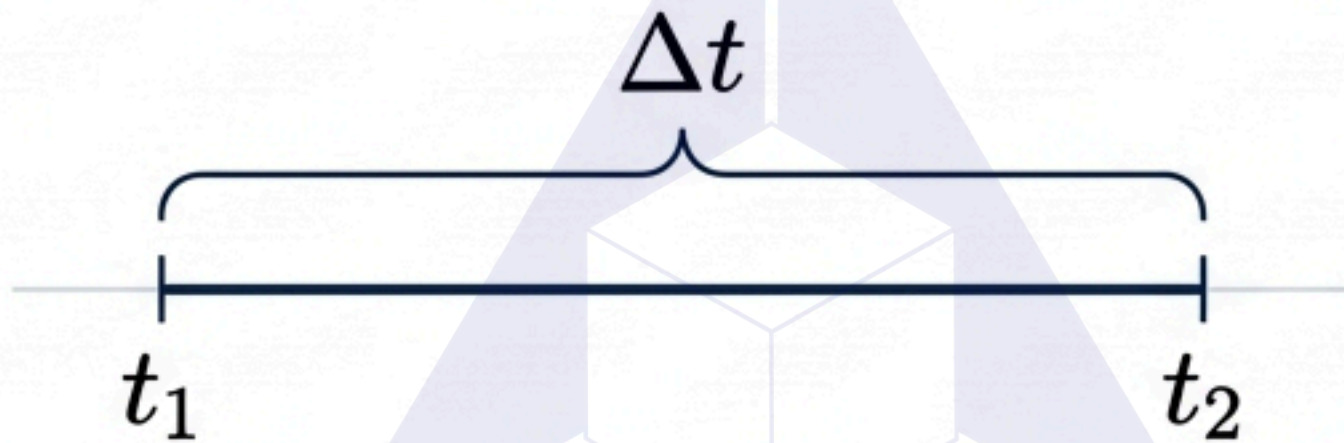
2.2 Instantaneous Velocity and Speed

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Why Average Velocity Is Not Enough

The Interval



Tells us how fast an object moved over a total, macro time interval (Δt).

The Blind Spots



Fails to tell us how fast the object was moving at specific, exact instants during that interval.

To know the velocity at a precise moment t , we must shrink the time interval.

Defining Velocity At An Instant

Velocity at an instant is the exact limit of the average velocity as the time interval becomes infinitesimally small.

$$v = \lim_{\Delta t \rightarrow 0} \frac{\Delta x}{\Delta t}$$

$$v = \frac{dx}{dt}$$

Differential coefficient of x with respect to t (Rate of change of position).



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$$E=mc^2$$



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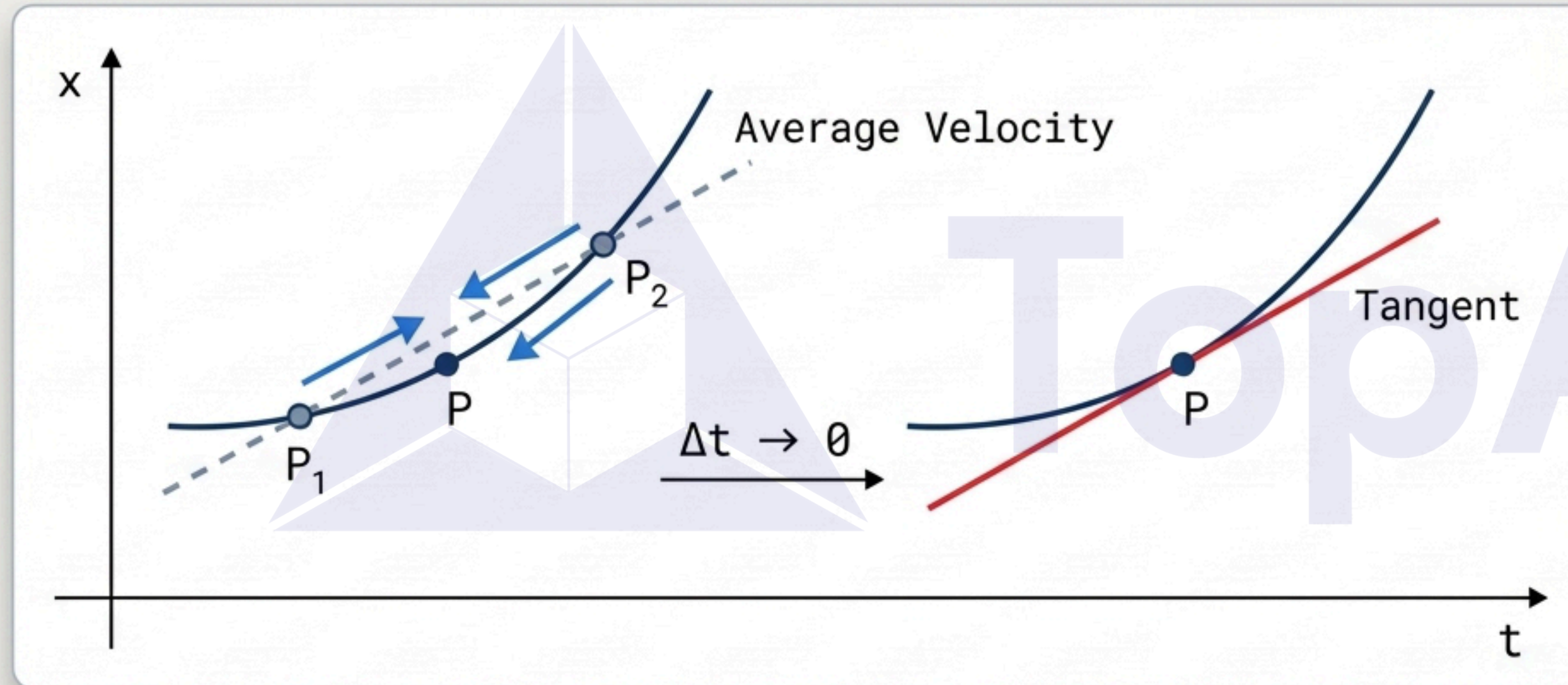
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The Slope Of The Tangent



Key Insight

As Δt approaches 0, the secant line transforms into the tangent to the curve at point P .

Velocity at t = Slope of tangent at that instant

Calculating The Limit

The Convergence Of Data

Using the exact textbook curve $x = 0.08t^3$ at $t = 4.0$ s. As we numerically shrink Δt , the average velocity converges to a precise mathematical limit.

Convergence Panel

Δt decreasing

2.0 s



1.0 s



0.5 s



0.1 s



0.01 s

$\Delta x / \Delta t$ converging

4.16



3.92



3.88



3.844



3.840

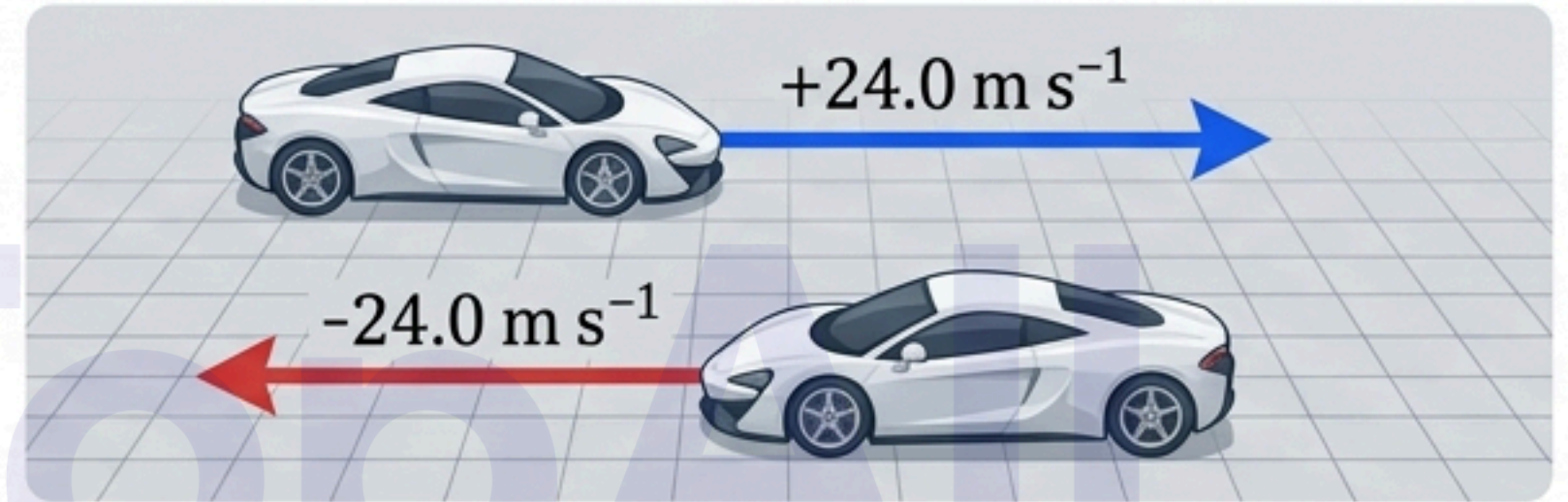
dx/dt at $t=4.0$ s is
exactly 3.84 m s^{-1}

Instantaneous Speed

Magnitude Without Direction

Scalar

Instantaneous speed is strictly the magnitude of instantaneous velocity. It ignores direction.



A velocity of $+24.0 \text{ m s}^{-1}$ and -24.0 m s^{-1} both yield an instantaneous speed of exactly 24.0 m s^{-1} .

Crucial Exam Nuance

- Average speed over an interval can be greater than the **magnitude of average velocity**.
- But instantaneous speed is ALWAYS exactly equal to the **magnitude of instantaneous velocity**. (Over an infinitesimal dt , path length equals displacement).

Chapter 2.2 Summary

Key Takeaways

Interval-Based

Average Velocity

- ✓ Tells overall pace over a macro duration Δt .
- ✓ Mathematically, it is the slope of a secant line.

Point-Based

Instantaneous Velocity

- ✓ Tells exact pace at a specific instant t .
- ✓ Mathematically, it is the slope of the tangent line (dx/dt).

Ignores Direction

Instantaneous Speed

- ✓ The exact magnitude of instantaneous velocity ($|v|$).
- ✓ Always a positive value regardless of the object's trajectory.



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