

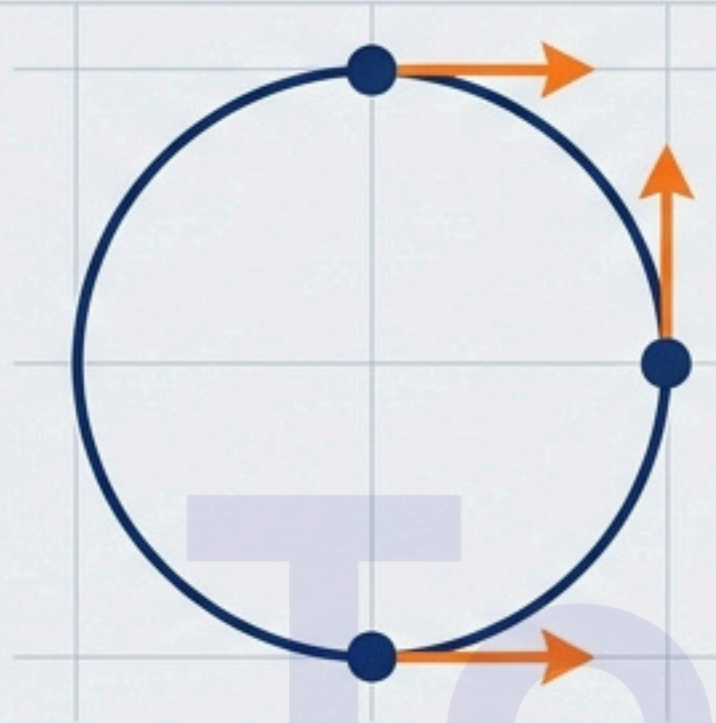
Uniform Circular Motion

Decoding the relationship between constant **speed**, changing **velocity**, and **centripetal acceleration**.



DEFINING THE MOTION

What Makes It Uniform?



Constant

The object covers equal distances along the circumference in equal intervals of time. The speed (magnitude of velocity) never changes.

Geometry

The object is constrained to a perfectly circular trajectory with a fixed radius (R) around a central origin.

Uniform = Constant Speed. But remember: Speed is a scalar. Velocity is a vector.

THE KINEMATIC PARADOX

Why There Is Acceleration

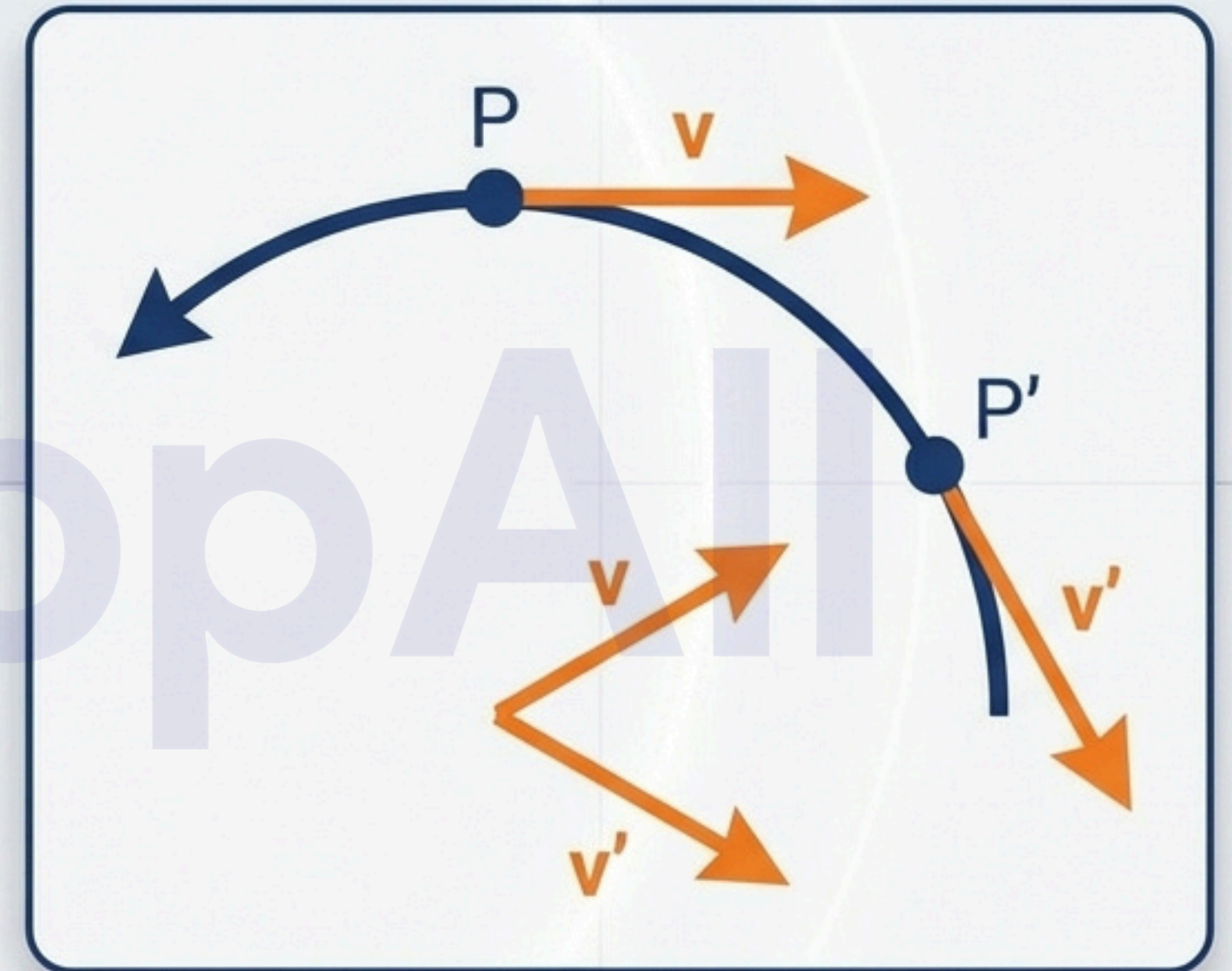


Step 1: Velocity is a vector. It requires both Magnitude (Speed) and Direction.

Step 2: Along a circular path, the tangential direction changes at every single infinitesimally small point.

Step 3: A change in direction mathematically guarantees a change in velocity (Δv).

Conclusion: Therefore, there is an acceleration, even if the speedometer reads a constant number.



$$a = \Delta v / \Delta t$$



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

$$E=mc^2$$



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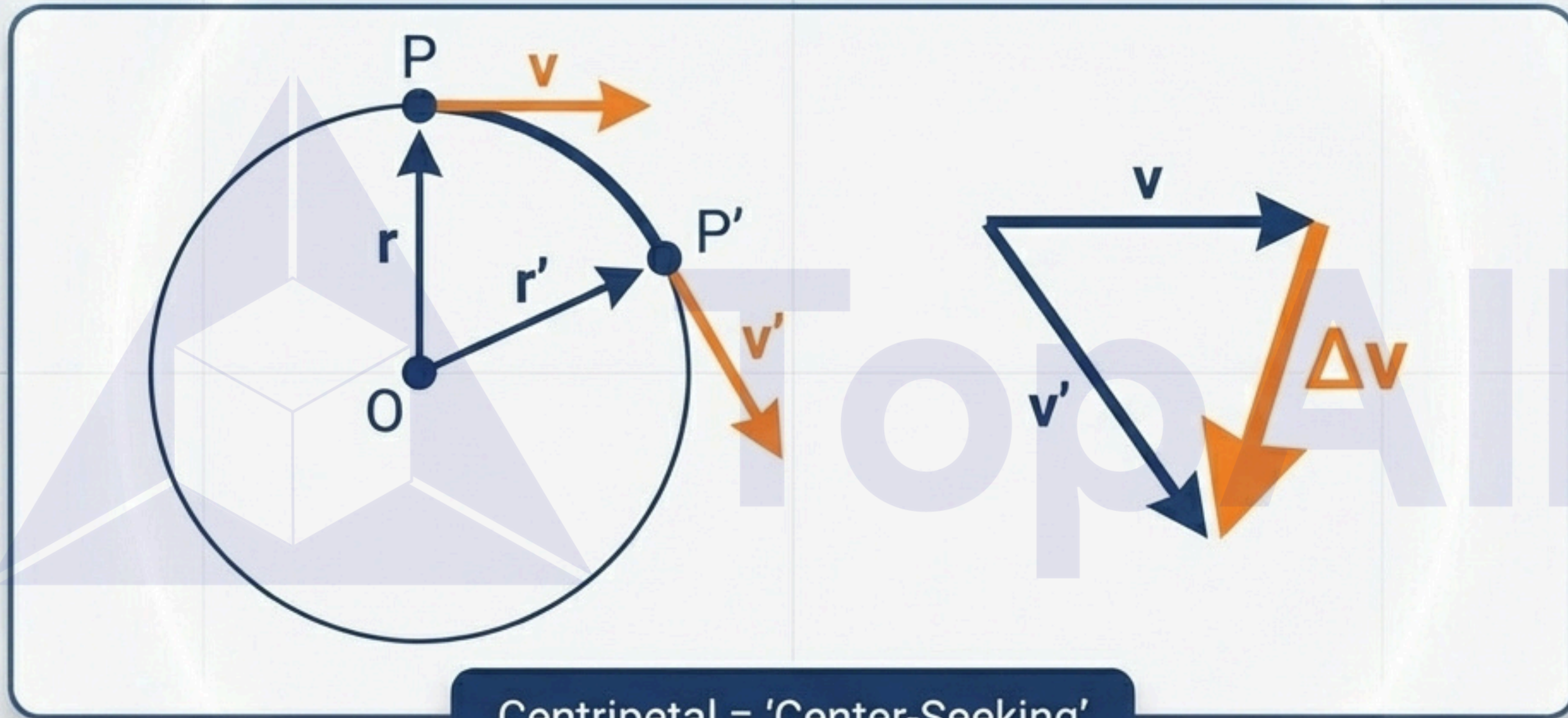
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Direction of Acceleration

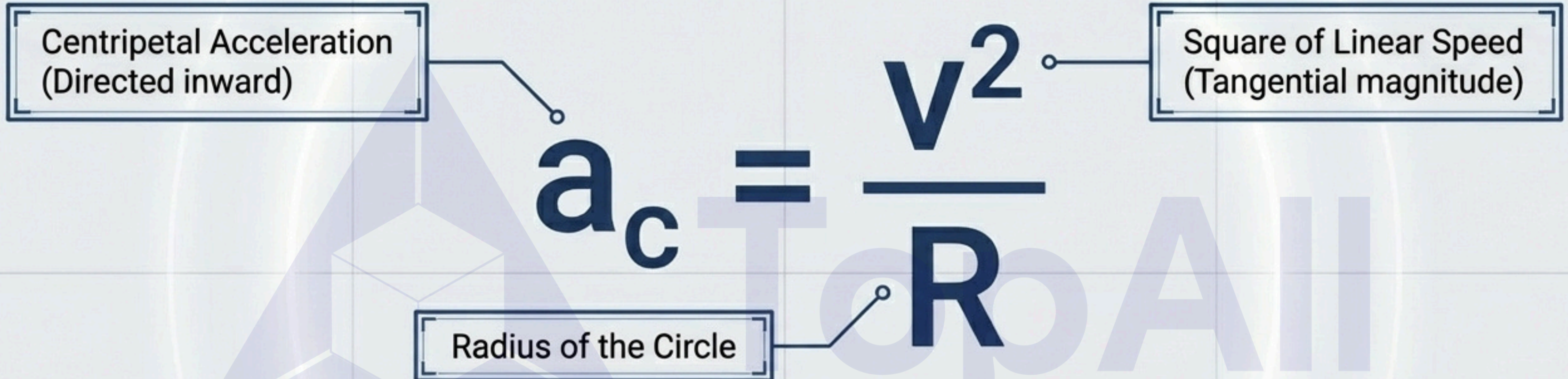


Centripetal = 'Center-Seeking'

As $\Delta t \rightarrow 0$, the angle between v and v' becomes infinitesimally small.

In this limit, the change in velocity (Δv) becomes strictly perpendicular to the path, pointing directly at the center.

Centripetal Acceleration Formula



The diagram shows the formula $a_c = \frac{v^2}{R}$ with three callout boxes. The first box, labeled 'Centripetal Acceleration (Directed inward)', points to a_c . The second box, labeled 'Square of Linear Speed (Tangential magnitude)', points to v^2 . The third box, labeled 'Radius of the Circle', points to R .

$$a_c = \frac{v^2}{R}$$

Direct Proportionality:

Higher speeds require exponentially more acceleration to keep the object in a circle (due to the v^2 term).

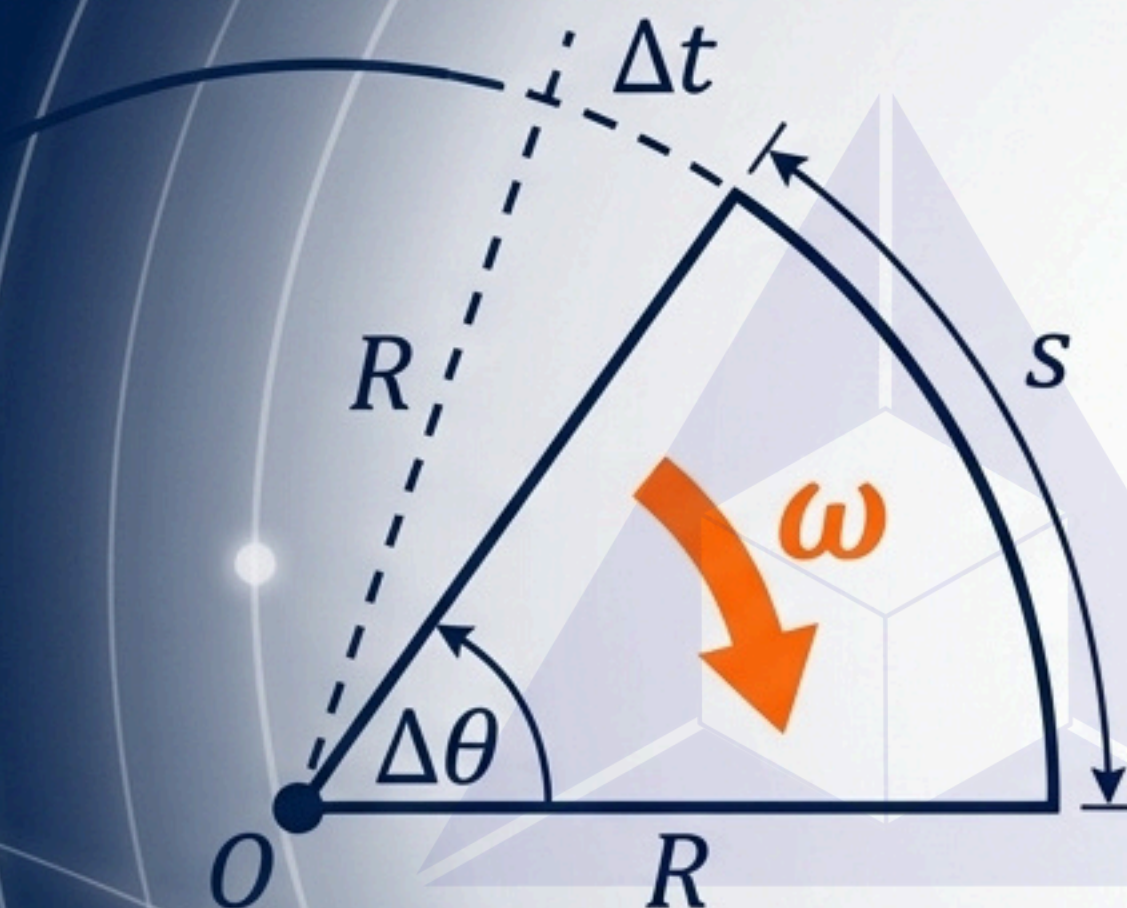
Inverse Proportionality:

Tighter turns (smaller R) require greater acceleration to maintain the same speed.

This is the exact acceleration required to constantly bend a straight-line path into a perfect circle.

THE ANGULAR PERSPECTIVE

Angular Speed Relation



Linear World

- Distance: s
- Speed: $v = \frac{\Delta s}{\Delta t}$

Angular World

- Angle: θ
- Angular Speed: $\omega = \frac{\Delta \theta}{\Delta t}$

The Bridge Equation

$$v = \omega R$$



Substitute v into $a_c = \frac{v^2}{R}$



$$a_c = \omega^2 R$$

Angular speed (ω) gives us a powerful alternative way to calculate acceleration when the rate of rotation is known.

Period and Frequency Form

Time Period (T): Time taken to complete exactly one full revolution.

Frequency (ν): Number of revolutions completed in one second ($\nu = 1/T$).

One Revolution: Equals an angular distance of 2π radians.

$$\omega = 2\pi\nu$$



$$v = 2\pi\nu R$$



$$a_c = 4\pi^2\nu^2 R$$

Mastery Check: You now have three distinct ways to find centripetal acceleration depending on your given data: Linear Speed (v), Angular Speed (ω), or Frequency (ν).



You've Learned the Theory.

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