Kinematics

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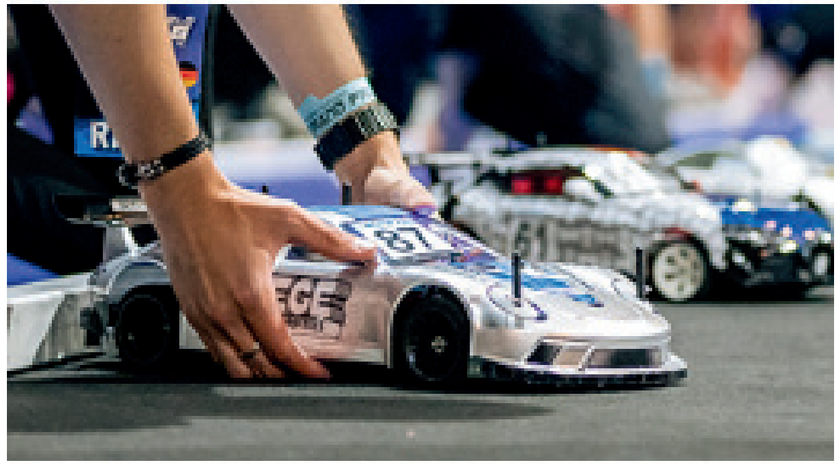
Kinematics is a part of science that focuses on understanding how things move. It doesn't worry about what makes them move, like forces or energy, but only about describing their motion. To do this, scientists look at a few important ideas:

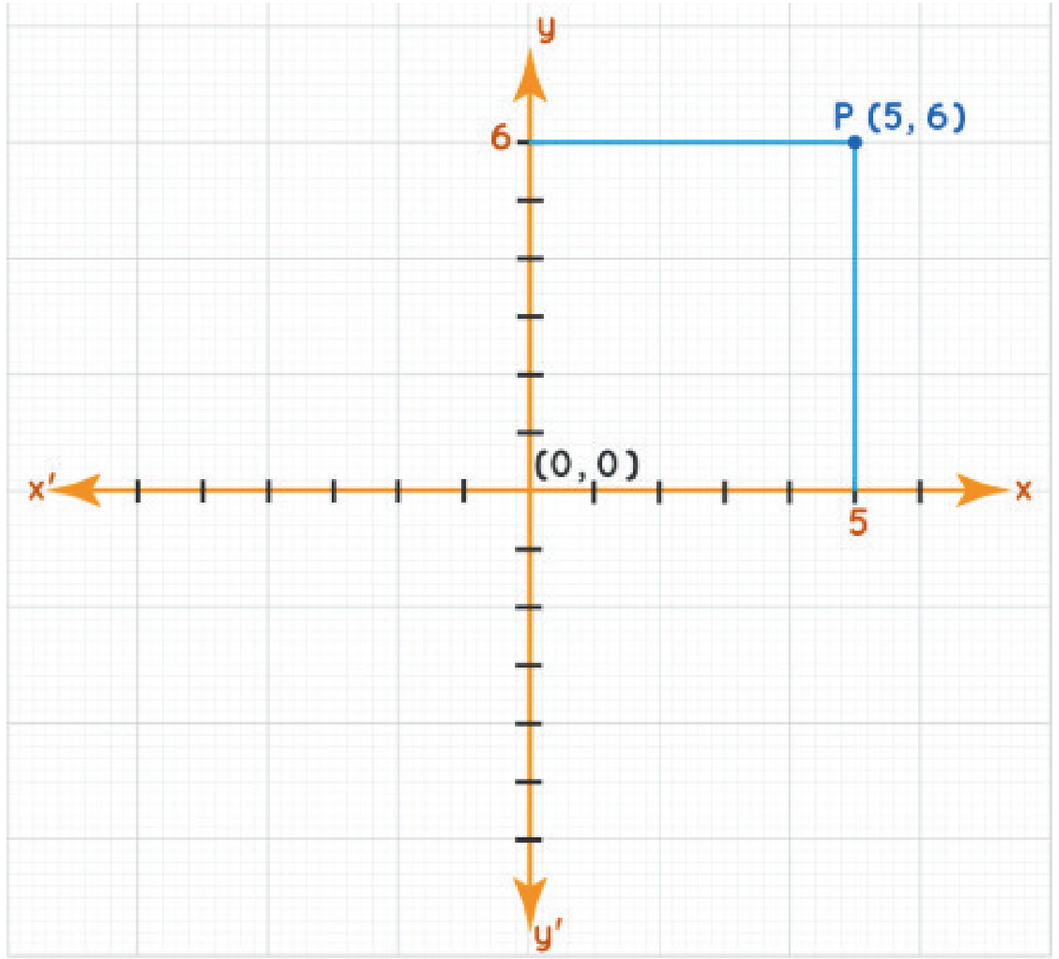


Position - The location of an object in space, often described with coordinates, for example, xyz in the coordinate plane.
Displacement - The change in position of an object.
Velocity - The rate of change of position with respect to time, indicating both speed and direction.
Acceleration - The rate of change of velocity with respect to time.
Time - The duration over which the motion occurs.

Position

One of the first concepts to understand is **position**, which refers to where an object is located at a specific moment in time. You can think of position like the coordinates on a map or a point on a number line—it's a way to describe exactly where something is in space relative to a chosen reference point.

Often, this position is represented on a **Cartesian plane**, which uses an x-axis and y-axis (and sometimes a z-axis in three dimensions) to pinpoint the exact location of an object in space.



Cartesian Plane

Distance and Displacement

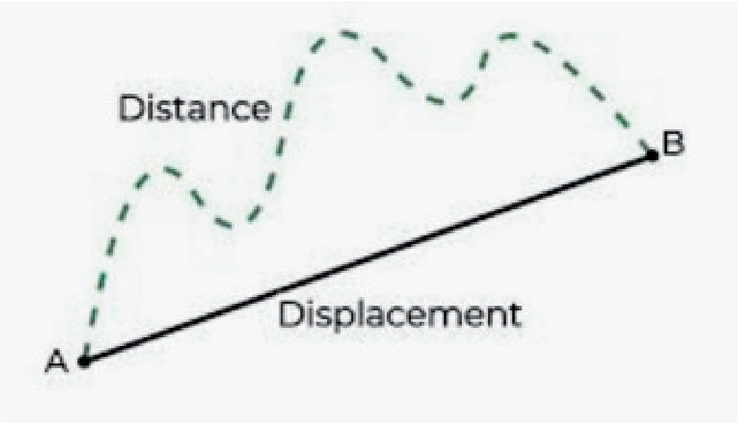
When an object moves, its position changes. This change in position is called **displacement**, which is a bit more specific than just "how far something traveled." Displacement not only measures the distance between the starting and ending points, but also **takes direction into account.**

This distinction between displacement and distance is important because kinematics often focuses on the precise details of motion, not just how much ground was covered. Displacement, as a vector quantity, gives both the size of the change and the direction it occurred, making it a fundamental idea in describing motion accurately.

Vector vs Scalar

In physics, quantities are classified as either **vectors** or **scalars**. A **scalar** is a quantity that has only magnitude, or size. For example, speed (like 60 miles per hour) and distance (like 10 meters) are scalars because they **don't include direction.**

On the other hand, a **vector** is a quantity that has both **magnitude and direction.** Velocity, for instance, might be 60 miles per hour to the north, and displacement could be 10 meters to the left. Vectors are critical for describing motion fully, as they provide more detailed information than scalars.



For example, if you walk a winding path of 8 meters but end up 2 meters from where you started, displacement is only 2 meters in the direction you ended up, even though you traveled a total of 8 meters. distance.

Velocity

Velocity tells you not just how fast something is moving, but also the direction it's going. This makes velocity a **vector** quantity. For example, if a car is driving at 60 miles per hour toward the east, its velocity includes both the speed (60 mph) and the direction (east).

Unlike speed, which only tells you how fast something is moving, velocity changes if either the speed or the direction changes. For instance, if a car turns a corner while going at the same speed, its velocity still changes because its direction has changed. A car speeding up or slowing down also changes its velocity.

$$v = \frac{\Delta d}{\Delta t} = \frac{d_B - d_A}{t_B - t_A}$$

Velocity is equal to the change in displacement divided by the change in time.

Acceleration

Acceleration describes how an object's velocity changes over time, and because it's a **vector**, it includes both a magnitude (how much the velocity changes) and a direction. This means acceleration doesn't just tell you how fast something is speeding up—it also accounts for slowing down or changing direction.

For example, when you press the gas pedal in a car, the car's velocity increases, showing positive acceleration. When you hit the brakes, the car slows down, which is negative acceleration, often called **deceleration**. Even if your speed stays constant while you turn a corner, that's still acceleration because the direction is changing.

$$a = \frac{\Delta v}{\Delta t} = \frac{v_B - v_A}{t_B - t_A}$$

Acceleration is equal to the change in velocity divided by the change in time.

Graphical Analysis

Graphs are a great way to understand how something moves over time. In a **position vs. time graph**, we can see where an object is at different times, while a **velocity vs. time graph** shows how fast it's going at different times. Both types of graphs use time on the x-axis (horizontal) and either position or velocity on the y-axis (vertical).

By looking at the shape of the lines, we can quickly tell what's happening. For example, on a **position vs. time graph**, a straight, slanted line means the object is moving at a constant speed. On a **velocity vs. time graph**, a flat line means the object is moving at the same speed, while a slanted line means the object is speeding up or slowing down.

These graphs make it easier to see patterns in motion and understand how things move!

Measuring Performance of the Sprint Car

Velocity and acceleration are important ways to measure how your sprint car performs. To figure out how well your car is doing right now, we're going to run a trial to find its **baseline performance**. A baseline is like a starting point—it's a set of measurements that shows what your car can do before you make any changes or improvements.

This baseline will help you compare your car's progress as you work to make it faster and better using the Engineering Design Process!