Physics

Week 1

Motion Along Straight Line

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Objectives

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The main objectives of today's lecture are:

- Review the relationship between position, displacement and average velocity
- Realize the difference between velocity and speed
- Practice calculating average speed and velocity
- Discuss instantaneous velocity and speed

Question?

Today's question:

A car has traveled uphill from the point A to point B with a constant speed of 30 km/h, and then downhill back to point A with a constant speed of 60 km/h.

What was the average speed of the car?

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b) Some other value
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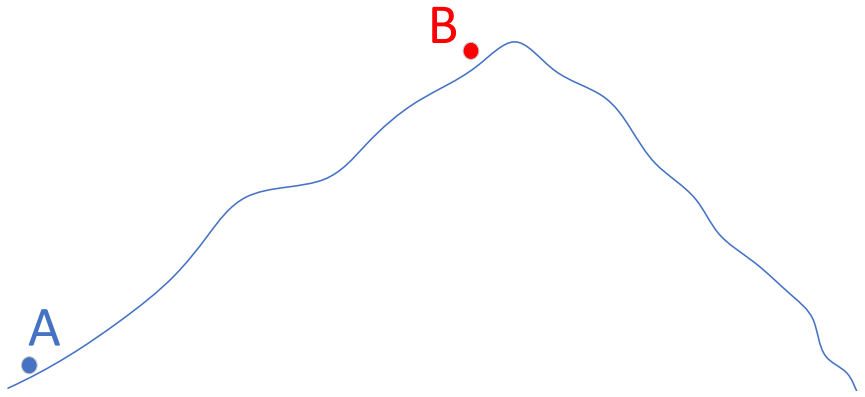


Motion and Time

Physics and Mechanics

One purpose of physics is to study the motion of objects—how fast they move, for example, and how far they move in a given amount of time.

Today, we study the basic physics of motion where the object (race car, tectonic plate, blood cell, or any other object) moves along a single axis.

- Such motion is called *one-dimensional motion*.

Image credit: dailyfx.com

Motion

The world, and everything in it, moves.

Even seemingly stationary things, such as a roadway, move with Earth's rotation, Earth's orbit around the Sun, the Sun's orbit around the center of the Milky Way galaxy, and that galaxy's migration relative to other galaxies.

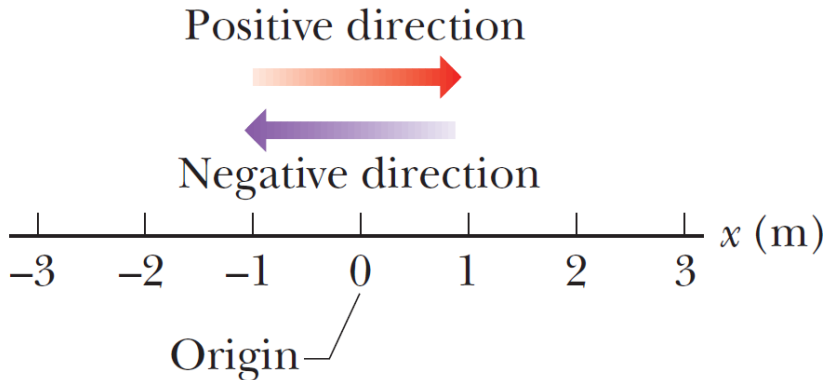
The classification and comparison of motions (called kinematics) is often challenging.

- What exactly do you measure, and how do you compare?

Image credit: newscientist.com

Position and Displacement

To locate an object means to find its position relative to some reference point, often the origin (or zero point) of an axis such as the x axis shown in the right figure.



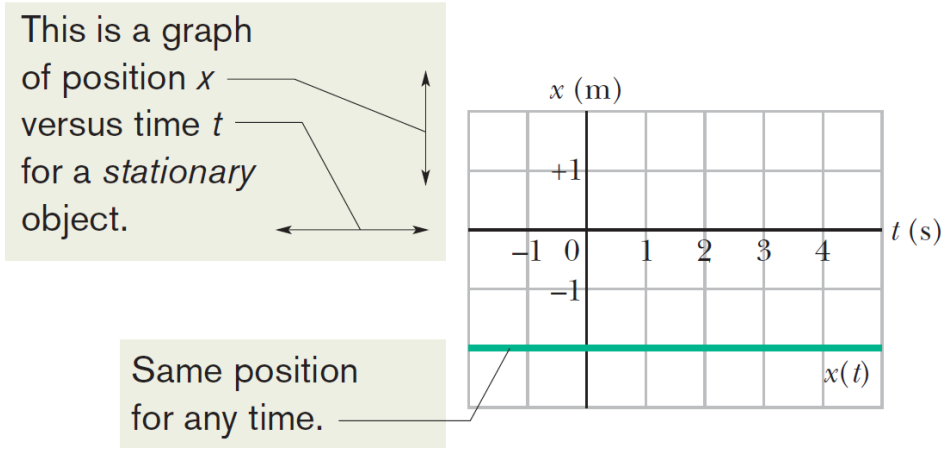
- The positive direction of the axis is in the direction of increasing numbers (coordinates), which is to the right.
- The opposite is the **negative direction.**
- A change from position x_1 to position x_2 is called a displacement Δx, where

$$\Delta x = x_2 - x_1$$

Position and Displacement

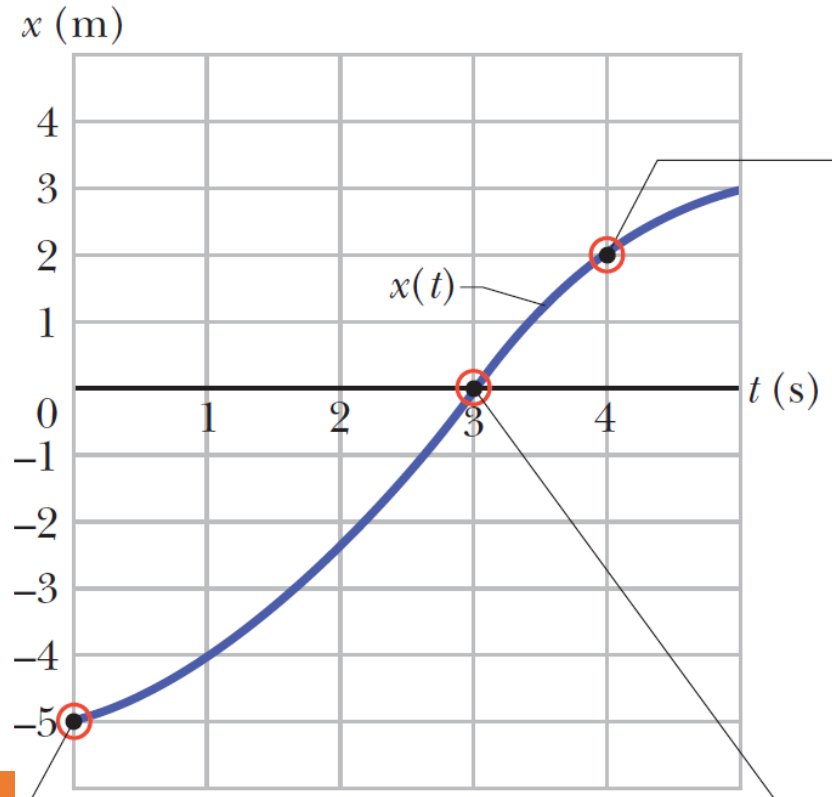
Displacement is an example of a vector quantity, which is a quantity that has both a direction and a magnitude.

- Its *magnitude* is the distance (such as the number of meters) between the original and final positions.
- Its *direction*, from an original position to a final position, can be represented by a plus sign or a minus sign if the motion is along a single axis.
- A compact way to describe position is with a graph of position x plotted as a function of time t — a graph of $x(t)$.



Position and Displacement

The figure here is more interesting because it involves motion.



At x = 2 m when t = 4 s

It is at position x = –5 m when time t = 0 s

At x = 0 m when t = 3 s

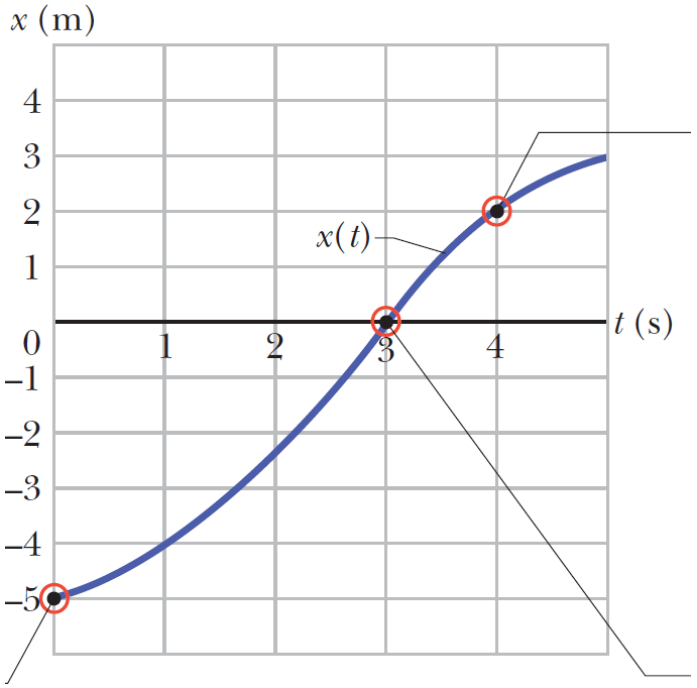
Average Velocity

Actually, several quantities are associated with the phrase “how fast.”

- One of them is the average velocity v_{avg}, which is the ratio of the displacement Δx to the particular time interval Δt when it occurs:

$$v_{avg} = \frac{\Delta x}{\Delta t} = \frac{x_2 - x_1}{t_2 - t_1}$$

- The notation means that the position is x_1 at time t_1 and then x_2 at time t_2.
- A common unit for v_{avg} is the meter per second (m/s).



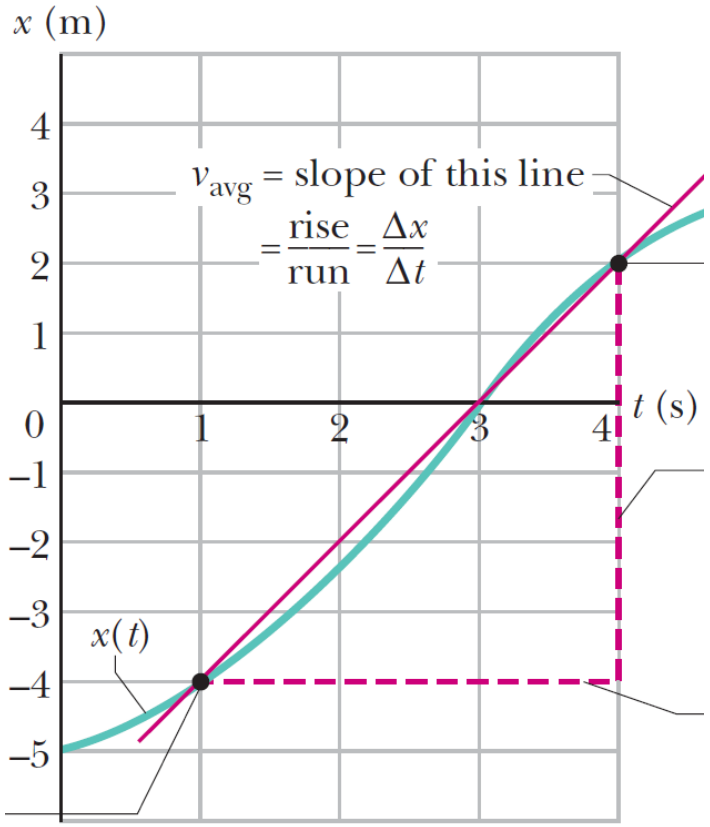
Average Velocity

On a graph of x versus t, v_{avg} is the slope of the straight line that connects two particular points on the $x(t)$ curve.

Like displacement, v_{avg} has both magnitude and direction (it is another vector quantity).

- Its magnitude is the magnitude of the **line's slope**.
- A positive v_{avg} (and slope) tells us that the line slants upward to the right; a negative v_{avg} (and slope) tells us that the line slants downward to the right.
- The average velocity v_{avg} always has the same sign as the displacement x because Δt is always positive.

$$v_{avg} = \frac{\Delta x}{\Delta t} = \frac{6\ \text{m}}{3\ \text{s}} = 2\ \text{m/s}$$



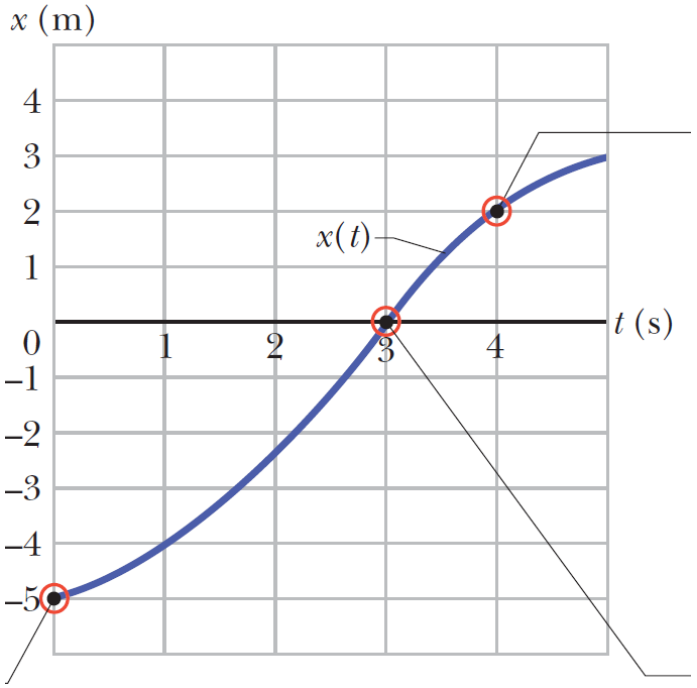
Average Speed

Average speed s_{avg} is a different way of describing "how fast" a particle moves.

- Whereas the average velocity involves the particle's displacement Δx, the average speed involves the total distance covered (for example, the number of meters moved), independent of direction:

$$s_{avg} = \frac{\text{total distance}}{\Delta t}$$

- Because average speed does *not* include direction, it lacks any algebraic sign.
- Sometimes s_{avg} is the same (except for the absence of a sign) as v_{avg}. However, the two can be quite different.



Average Velocity and Speed: Exercise

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You drive a truck along a straight road for 8.4 km at 70 km/h, at which point the truck runs out of gasoline and stops. Over the next 30 min, you walk another 2.0 km farther along the road to a gasoline station, pump the gasoline, pay for it, and walk back to the truck for another 45 min.

The 4 questions to answer in this exercise are:

1. What is your overall displacement from the beginning of your drive to arrival at the station?
2. What is the time interval Δt from the beginning of your drive to your arrival at the station?
3. What is your average velocity v_{avg} from the beginning of your drive to your arrival at the station? Find it both numerically and graphically.
4. What is your average speed s_{avg} from the beginning of your drive to your return to the truck with the gasoline?

Average Velocity and Speed: Exercise

1. What is your overall displacement from the beginning of your drive to your arrival at the station?

2. What is the time interval Δt from the beginning of your drive to your arrival at the gas station?

Average Velocity and Speed: Exercise

3. What is your average velocity v_{avg} from the beginning of your drive to your arrival at the station? Find it both numerically and graphically.

Average Velocity and Speed: Exercise

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Instantaneous Velocity

You have now seen two ways to describe how fast something moves: average velocity and average speed, both of which are measured over a time interval Δt.

- However, the phrase "how fast" more commonly refers to how fast a particle is moving at a given instant—its instantaneous velocity (or simply velocity) v.

The velocity at any instant is obtained from the average velocity by shrinking the time interval Δt closer and closer to 0.

- As Δt dwindles, the average velocity approaches a limiting value, which is the velocity at that instant:

$$v = \lim_{\Delta t \to 0} \frac{\Delta x}{\Delta t} = \frac{dx}{dt}$$

- Velocity is another vector quantity and thus has an associated direction.

Instantaneous Velocity and Speed

Speed is the magnitude of velocity; that is, speed is velocity that has been stripped of any indication of direction, either in words or via an algebraic sign.

- A velocity of 5 m/s and one of −5 m/s both have an associated speed of 5 m/s.
- The speedometer in a car measures speed, not velocity (it cannot determine the direction).

Q: The following equations give the position $x(t)$ of a particle in four situations (in each equation, x is in meters, t is in seconds, and $t > 0$):

1. $x(t) = 3t - 2$
2. $x(t) = -4t^2 - 2$
3. $x(t) = 2/t^2$
4. $x(t) = -2$

- (a) In which situation is the velocity v of the particle constant?
- (b) In which is v in the negative x direction?

Question?

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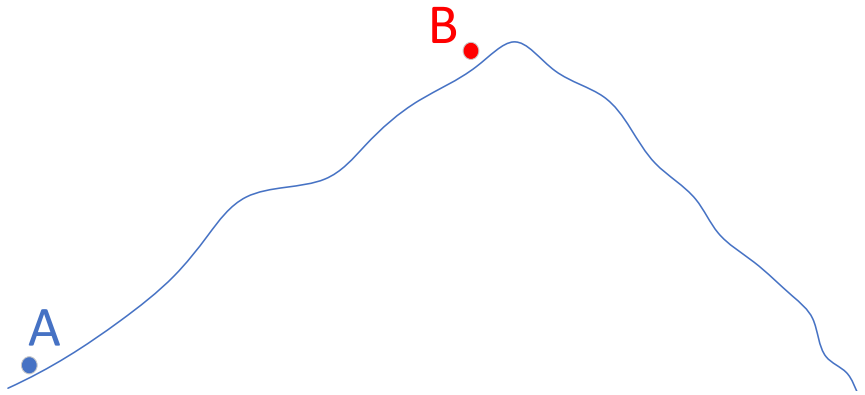

Thank you for your attention!

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