Honors Physics
Unit 1: Kinematics

Slides

Scalars & Vectors

Scalars & Vectors

In physics, we deal with two kinds of quantities: scalars and vectors

1. **Scalars**: only have magnitude

2. **Vectors**: have magnitude AND direction

Magnitude = size, amount, how much

Scalars

- Only have magnitude

- For example:
  - Temperature
  - Mass
  - Density
  - Time

Vectors

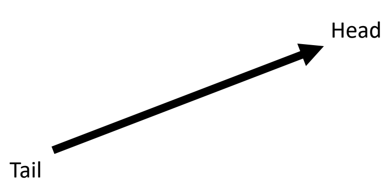
- Have magnitude AND direction

- For example:
  - Velocity
  - Acceleration
  - Force

How do we represent vectors?

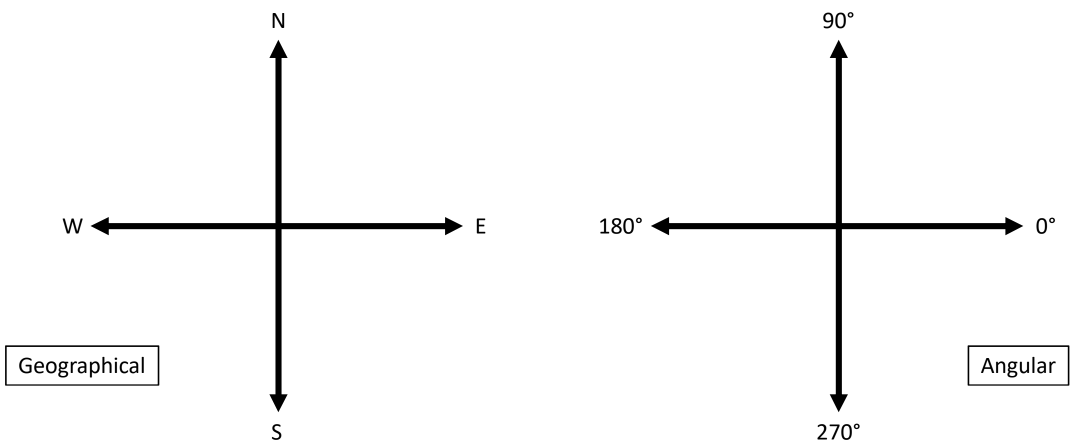
- In writing:
  - A bold letter: **v**
  - A letter with an arrow over it: $\vec{v}$

- Visually:



The length of the vector arrow corresponds to the magnitude of the vector

Frames of Reference



Signs

By convention, certain directions are considered positive (+) and others are considered negative (-)

Positive (+)

- North, East, up, right, 0°, 90°

Negative (-)

- South, West, down, left, 180°, 270°

Writing a Vector

- Give the magnitude (number and unit) AND the direction relative to a frame of reference

- For example:
  - 5 m, N
  - 2 m/s, 180°
  - 10 Newtons, SE

Adding Vectors

Vector Addition

Vectors can be added together

$$\vec{A} + \vec{B} = \vec{C}$$

The sum of the vectors is called the **resultant vector**

- $\vec{C}$ in the above example

Vector Addition

Three cases, three techniques:

- Vectors lie along the same line
  - 0° angle between vectors
- Vectors are perpendicular
  - 90° angle between vectors
- Arbitrary vectors
  - Any angle between vectors

Adding Vectors Along One Line

To add two or more vectors that are directed along the same line (for example, North-South or East-West):

1. Give each vector's magnitude the proper (+) or (-) sign depending on the vector's direction
2. Add the magnitudes and signs together

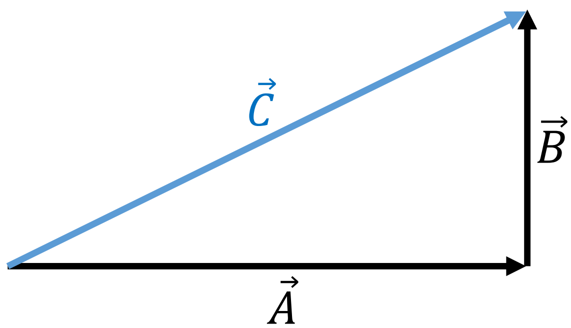
The sign of the sum tells you the direction of the resultant vector

Adding Vectors In Perpendicular Directions

To add two vectors that point in perpendicular directions (for example, one is East and the other is North), you must use the Pythagorean Theorem.

The two vectors you are adding make up the legs of a right triangle. The vector sum is the hypotenuse of the right triangle. Calculate the magnitude with

$$C = \sqrt{A^2 + B^2}$$



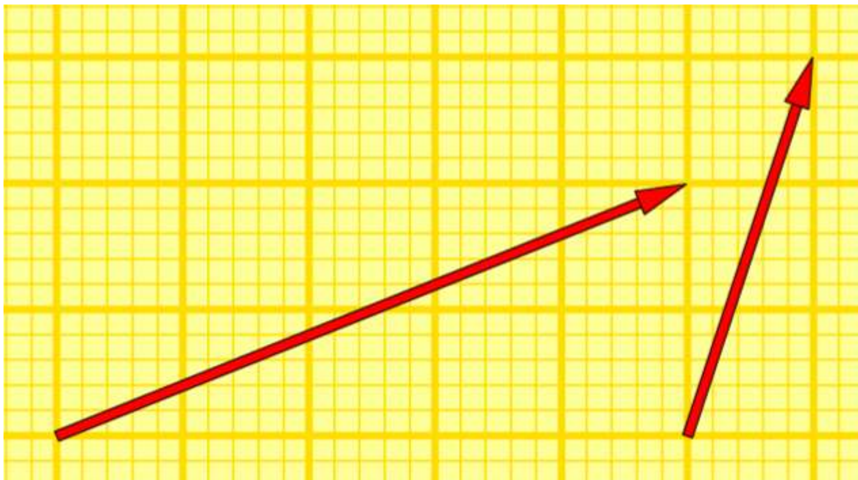
$$\vec{C} = \vec{A} + \vec{B}$$

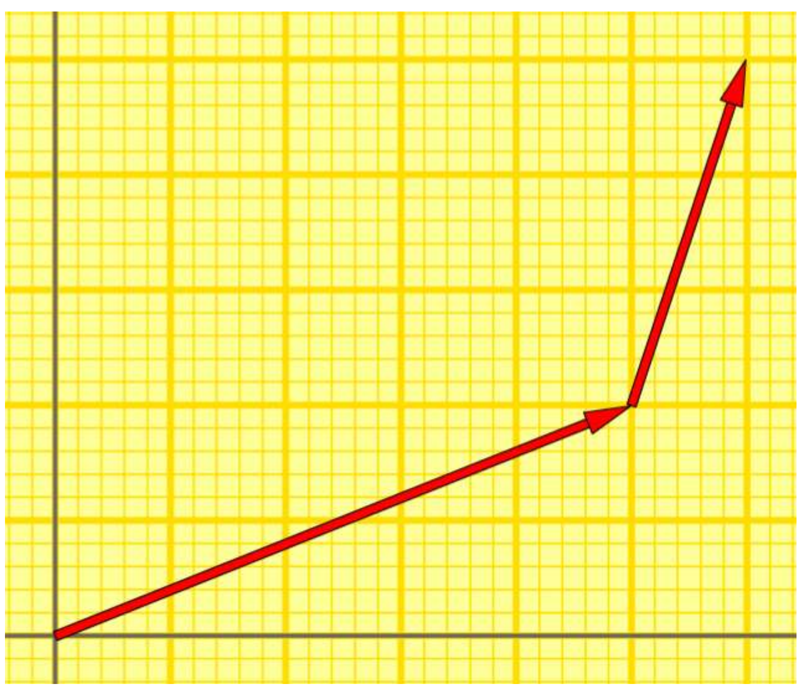
$$C = \sqrt{A^2 + B^2}$$

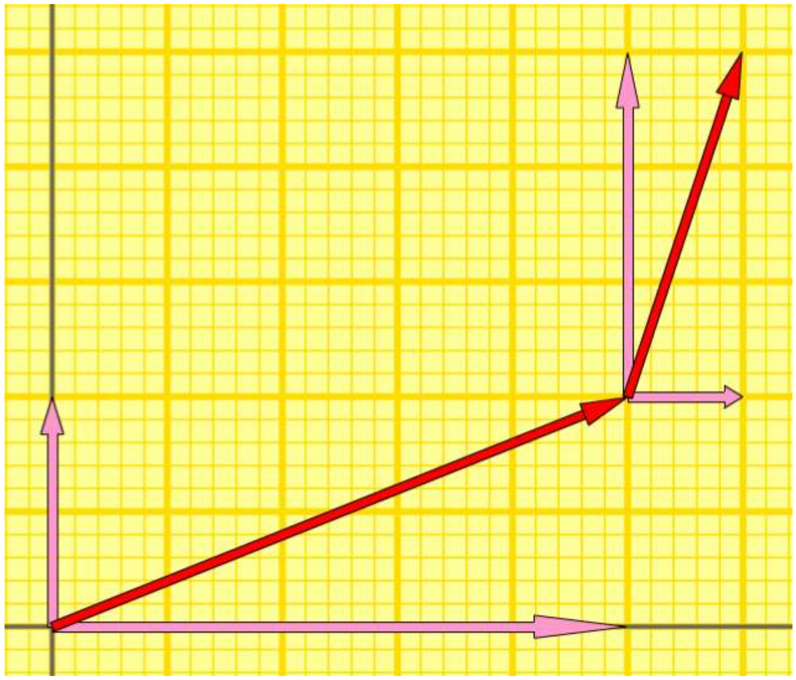
Adding Vectors In Any Directions

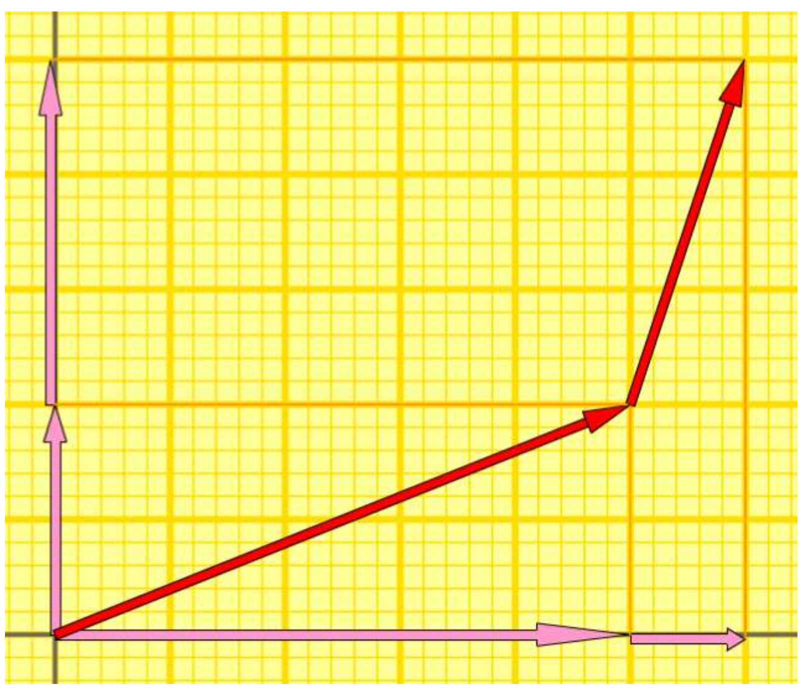
ANY vectors can be added by adding their vector components:

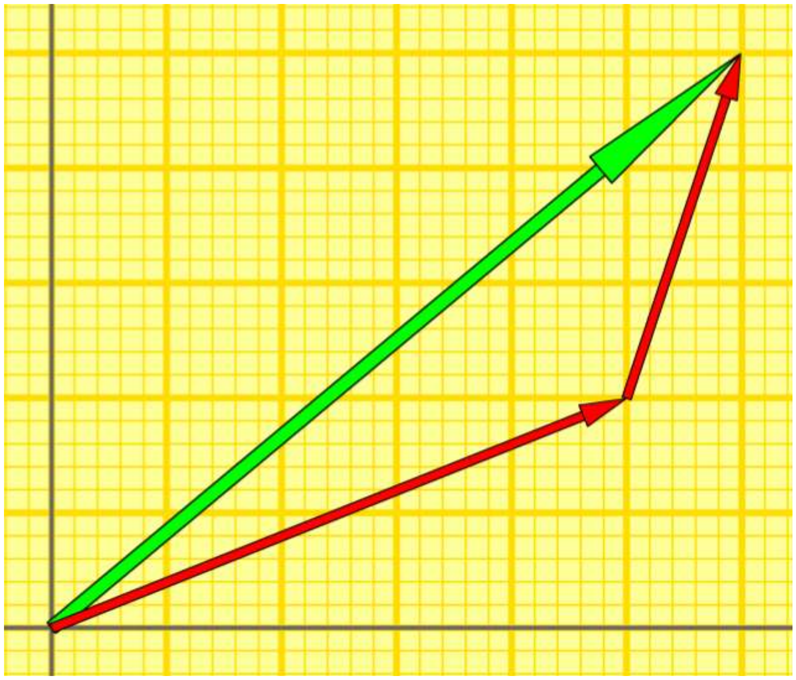
1. Break all vectors into their *x*- and *y*-components (Include the correct positive or negative sign!)
2. Add together all the *x*-components to get the *x*-component of the resultant vector
3. Add together all the *y*-components to get the *y*-component of the resultant vector
4. Use the components of the resultant to calculate the magnitude and angle of the resultant vector

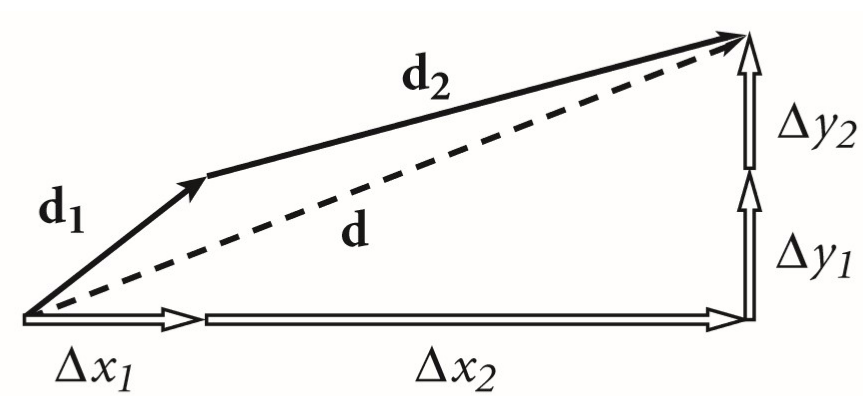











$\mathbf{d_2}$
Δy_2
$\mathbf{d_1}$
$\mathbf{d}$
Δy_1
Δx_1
Δx_2

Kinematics

How can we adequately describe motion?

Kinematics: The study of how objects move; the study of motion.

What are the elements of kinematics?

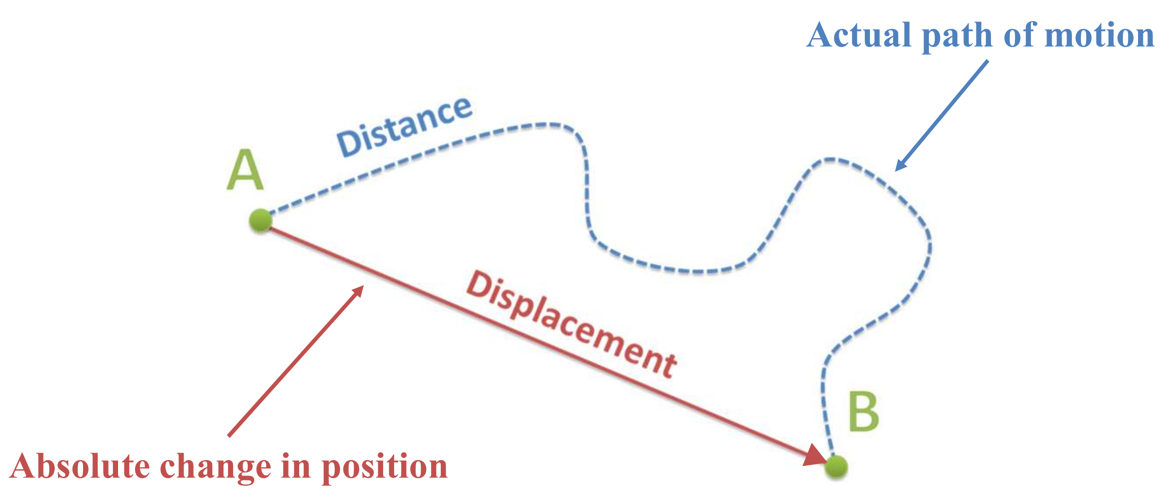
- "How far" → Distance & Displacement
- "How fast" → Speed & Velocity
- "Speeding up or slowing down" → Acceleration

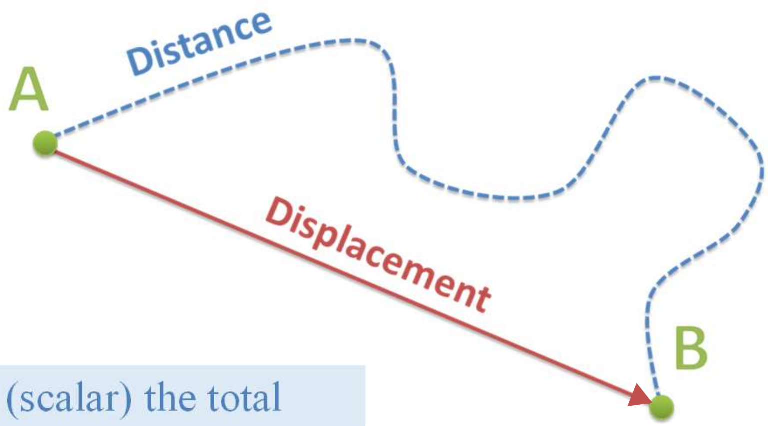
Distance & Displacement

How can we describe changes in position?

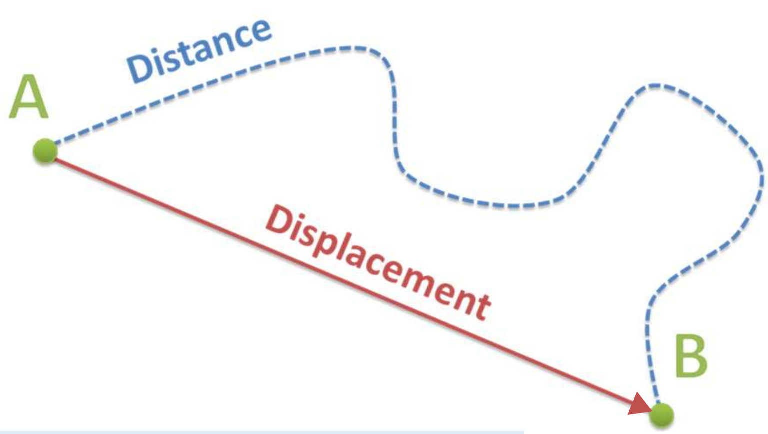
Measuring Changes in Position

How did an object move?

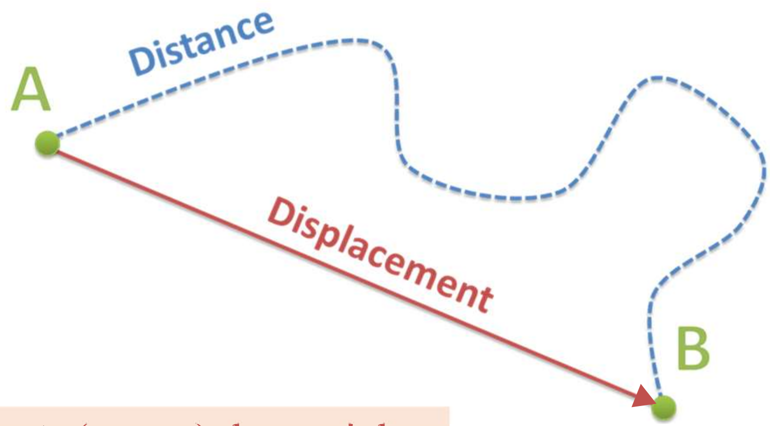




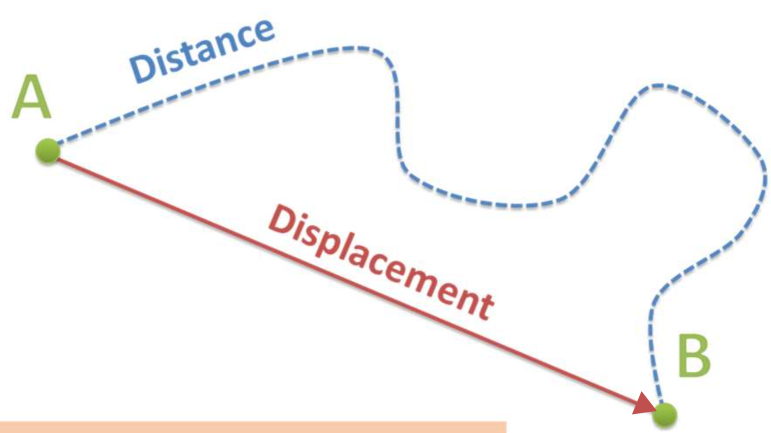
Distance: (scalar) the total length travelled along the path of motion from the start position to the end position



- Distance is the curvy blue line
- Distance is **always positive**
- Does not have a direction (scalar)
- “How far” the object actually moved



Displacement: (vector) the straight-line, absolute *change in position*; the difference between the start position and the end position



- Displacement is the red straight line
- May be positive or negative based on direction
- Must have a magnitude and direction (vector)
- "How much" position changed from start to end

Symbols

In physics, we use the Greek capital letter delta (Δ) to mean the **change in** something from the initial value to the final value

$$\Delta r = r_f - r_i$$

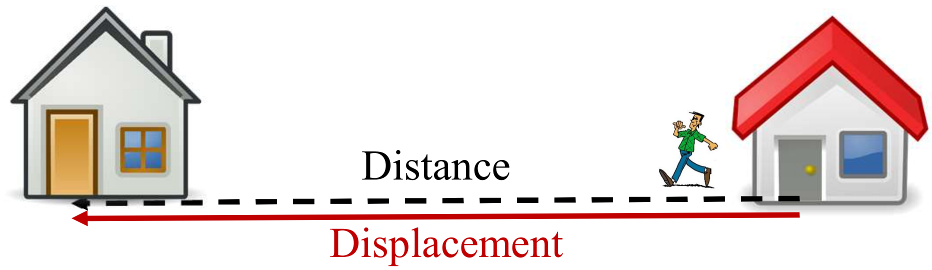
"change in *r* = final *r* – initial *r*"

Displacement

$$\underbrace{\Delta x}_{\text{displacement}} = \underbrace{x_f}_{\text{final position}} - \underbrace{x_i}_{\text{initial position}}$$

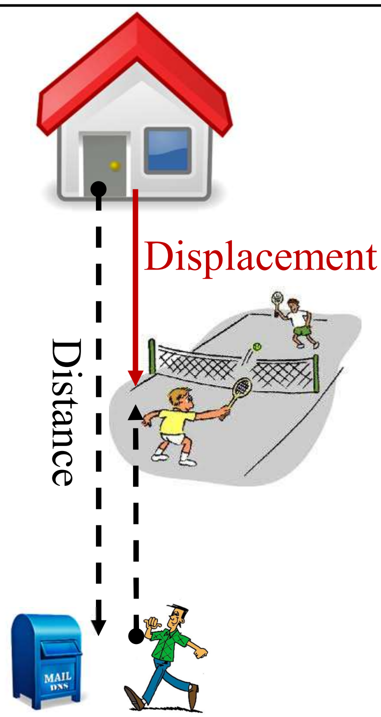
"displacement = final position – initial position"

Herman walks west from his home to his grandfather's home. They live on the same street. The street is perfectly straight.



His **distance** traveled is indicated by the black dashed line.
His **displacement** is indicated by the solid red line.

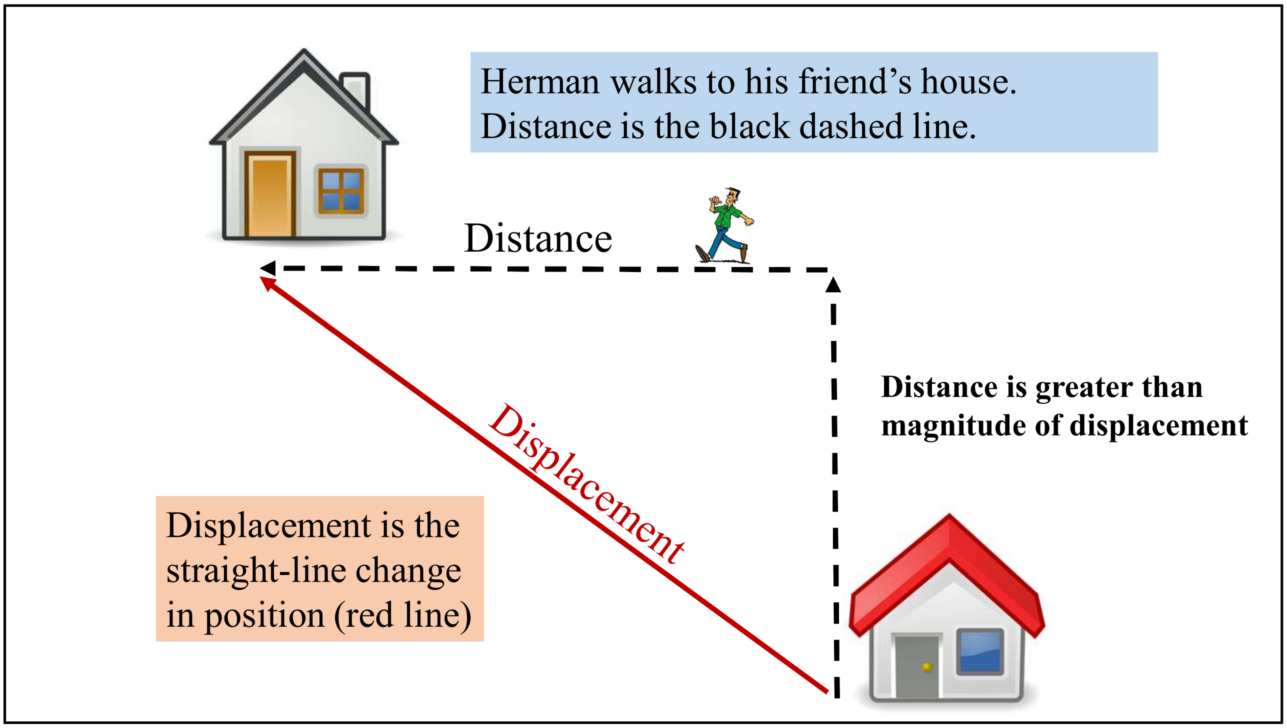
Distance and magnitude of displacement are equal.

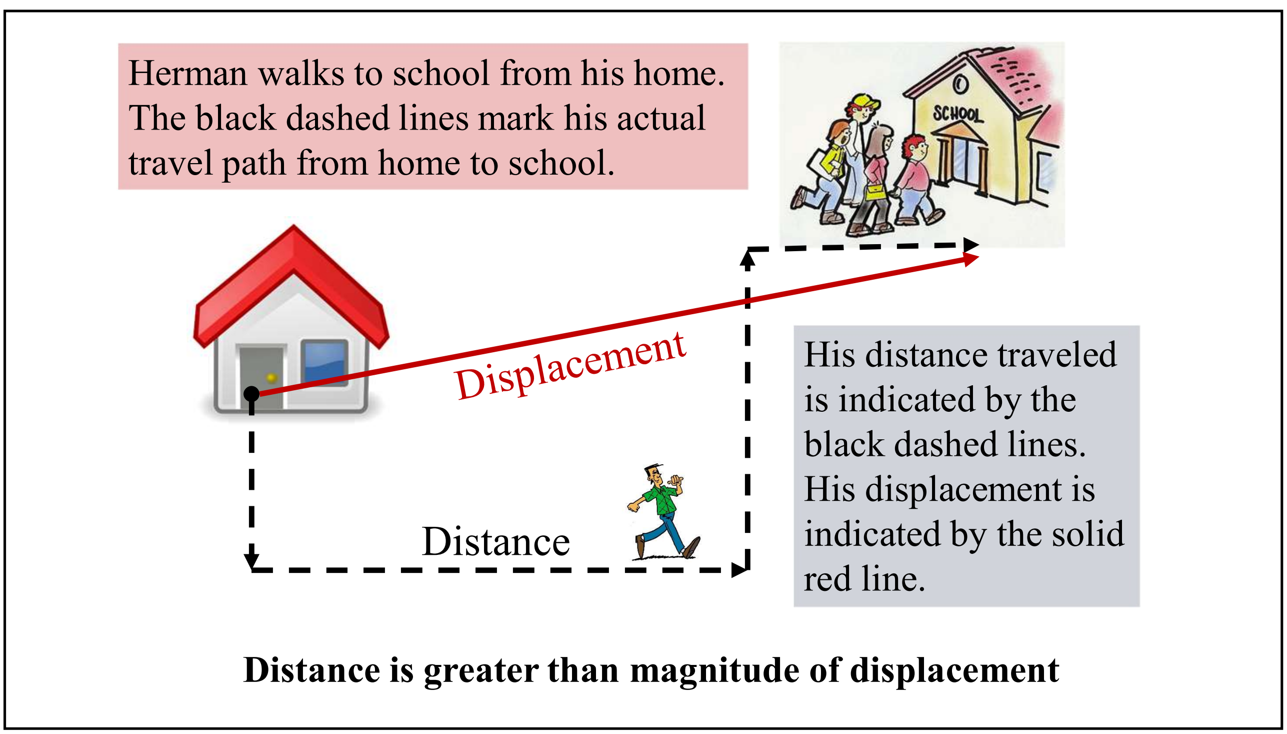


Herman walks south from his home to the post box. He then walks north to the tennis courts.

His **distance** traveled is indicated by the black dashed lines. His **displacement** is indicated by the solid red line.

Distance is greater than magnitude of displacement.


Herman walks to his friend's house.
Distance is the black dashed line.
Distance
Displacement
Distance is greater than
magnitude of displacement
Displacement is the
straight-line change
in position (red line)


Herman walks to school from his home.
The black dashed lines mark his actual
travel path from home to school.
SCHOOL
Displacement
His distance traveled
is indicated by the
black dashed lines.
His displacement is
indicated by the solid
red line.
Distance
Distance is greater than magnitude of displacement

Finding Distance & Displacement

1. Draw a sketch of the movement of the object. Clearly identify and mark the start and end points
2. Draw the displacement vector on your sketch: draw a straight arrow that begins at the start point and ends at the end point
3. Find the value of the displacement by adding together the vectors of the step by step movements
4. Find the value of the distance by adding the lengths of the step by step movements

Shortcut: If the start and end points are the same, the displacement = 0

Motion in 1-Dimension

1. You walk 10 meters east, stop, walk 30 m east.

- Calculate distance
- Calculate displacement

2. You walk 20 meters east, turn, walk 5 meters west.

- Calculate distance
- Calculate displacement

1. You walk 10 meters east, stop, walk 30 m east.
- Calculate distance
- Calculate displacement

d = 10 m + 30 m = 40 m

Δx = (+10 m) + (+30 m) = +40 m = 40 m E

2. You walk 20 meters east, turn, walk 5 meters west.
- Calculate distance
- Calculate displacement

d = 20 m + 5 m = 25 m

Δx = (+20 m) + (-5 m) = +15 m = 15 m E

Motion in 1-Dimension

3. You walk 15 m north, turn, walk 50 m south.
- Calculate distance
- Calculate displacement

4. Example: You walk 20 m south, turn, walk 40 m north.
- Calculate distance
- Calculate displacement

3. You walk 15 m north, turn, walk 50 m south.
• Calculate distance
• Calculate displacement

d = 15 m + 50 m = 65 m

Δx = (+15 m) + (-50 m) = -35 m = 35 m S

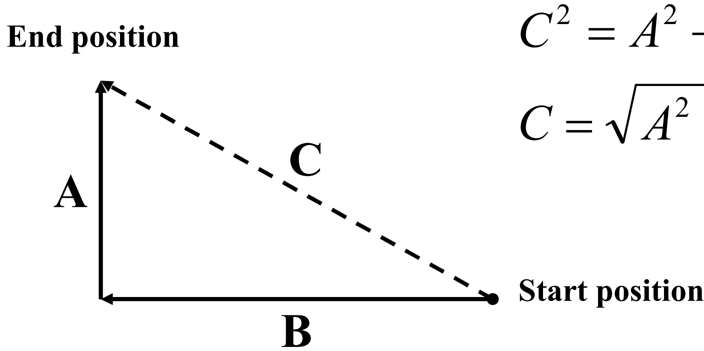
4. Example: You walk 20 m south, turn, walk 40 m north.
• Calculate distance
• Calculate displacement

d = 20 m + 40 m = 60 m

Δx = (-20 m) + (+40 m) = +20 m = 20 m N

2-Dimensional motion

- Paths of travel are at right angles
- Determine the displacement (C) based on distance of two segments at right angles.



$$C^2 = A^2 + B^2$$

$$C = \sqrt{A^2 + B^2}$$

Calculate distance and displacement.
(use Pythagorean Theorem for displacement)

Walk 10 m north, stop, walk 10 m west.

Walk 12 m north, turn, 6 m east

Walk 14 m west, turn, walk 8 m south

Walk 10 m north, stop, walk 10 m west.

d = 20 m
Δx = 14.1 m NW

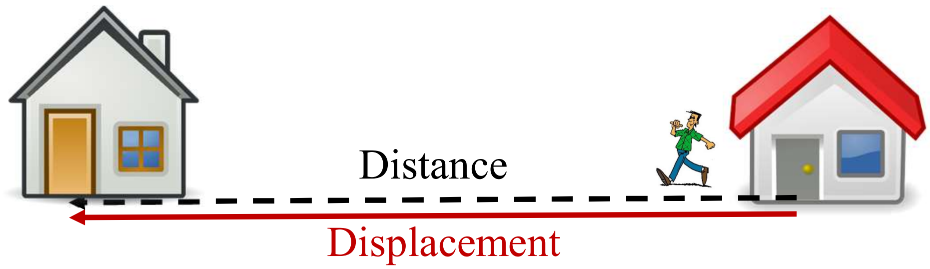
Walk 12 m north, turn, 6 m east

d = 18 m
Δx = 13.4 m NE

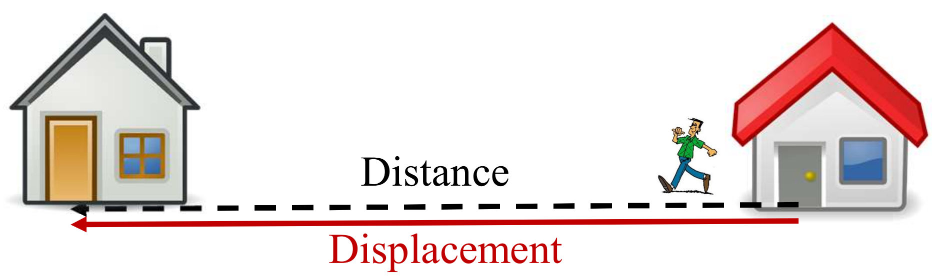
Walk 14 m west, turn, walk 8 m south

d = 22 m
Δx = 16.1 m SW

Herman walks west from his home to his grandfather's home. They live on the same street. The street is perfectly straight. The houses are 700 meters apart.



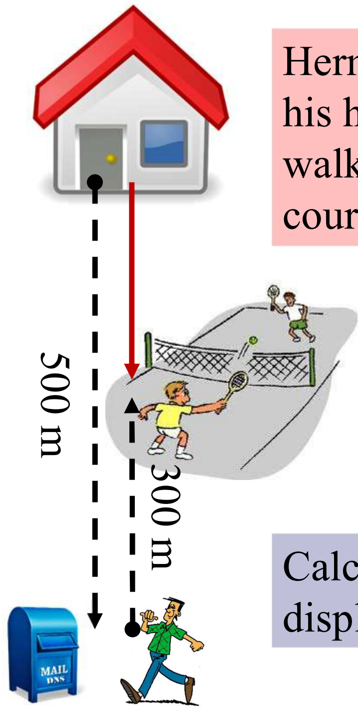
Calculate distance and displacement.



Calculate distance and displacement.

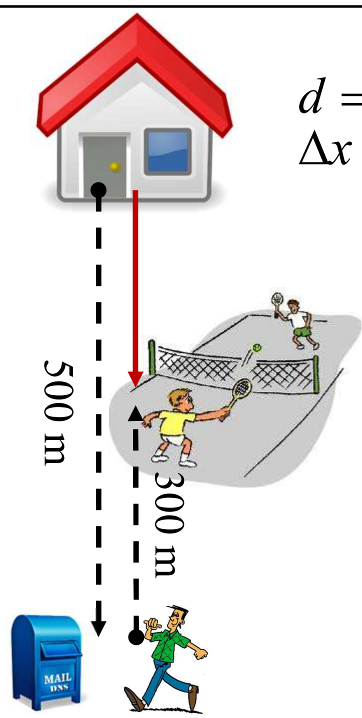
$d = 700$ m

$\Delta x = 700$ m W



Herman walks 500 m south from his home to the post box. He then walks 300 m north to the tennis courts.

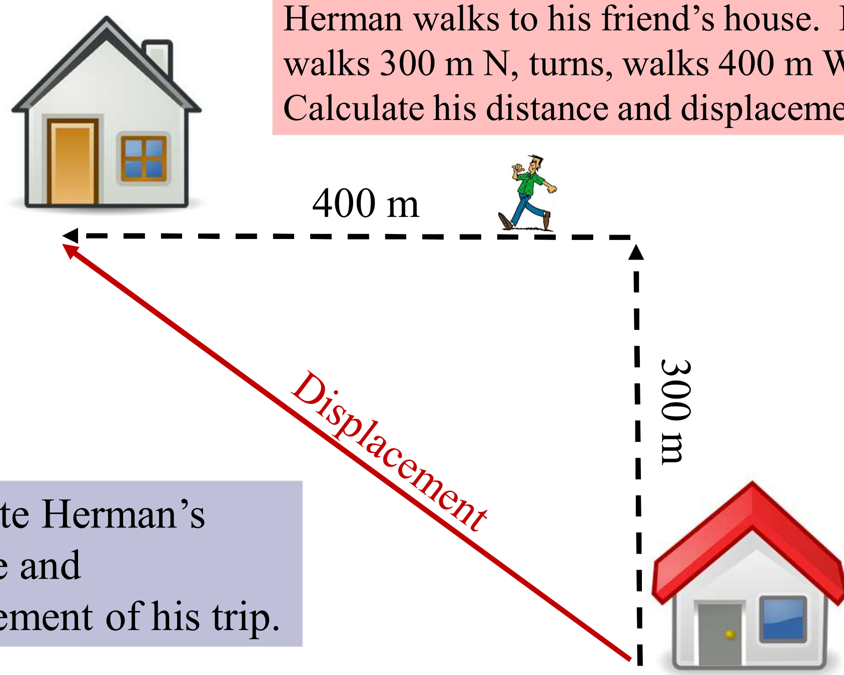
Calculate Herman's distance and displacement of his trip.



$$d = 500m + 300m = 800m$$
$$\Delta x = -500m + 300m = -200m$$

d = 800 m
Δx = 200 m S

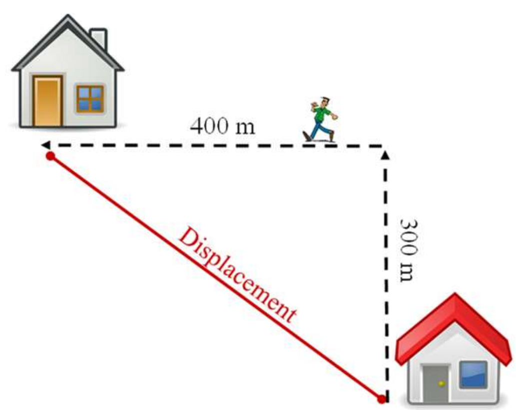
Herman walks to his friend's house. He walks 300 m N, turns, walks 400 m W. Calculate his distance and displacement.



Calculate Herman's distance and displacement of his trip.

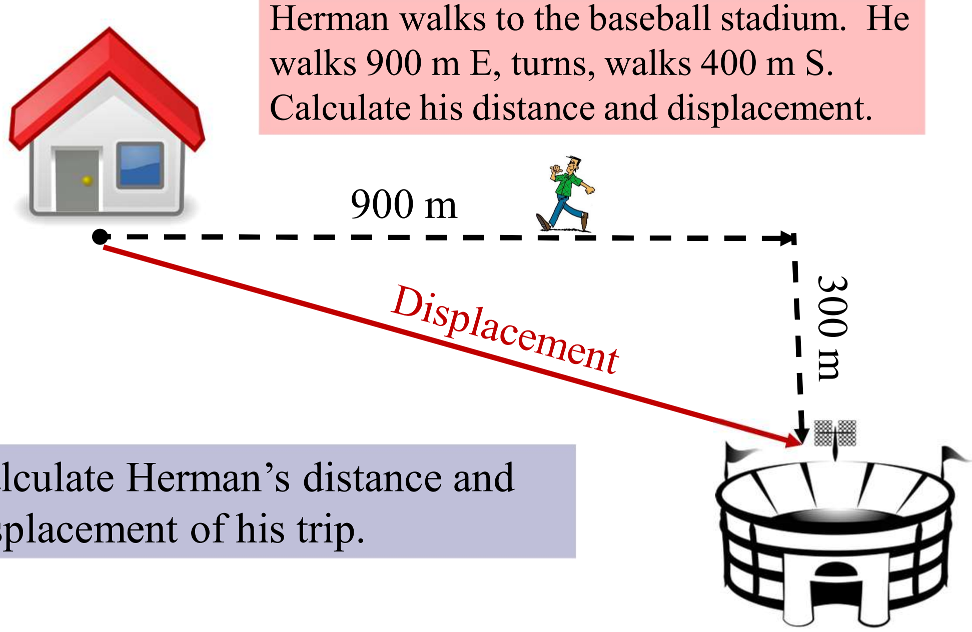
d = 700 m

Δx = 500 m NW



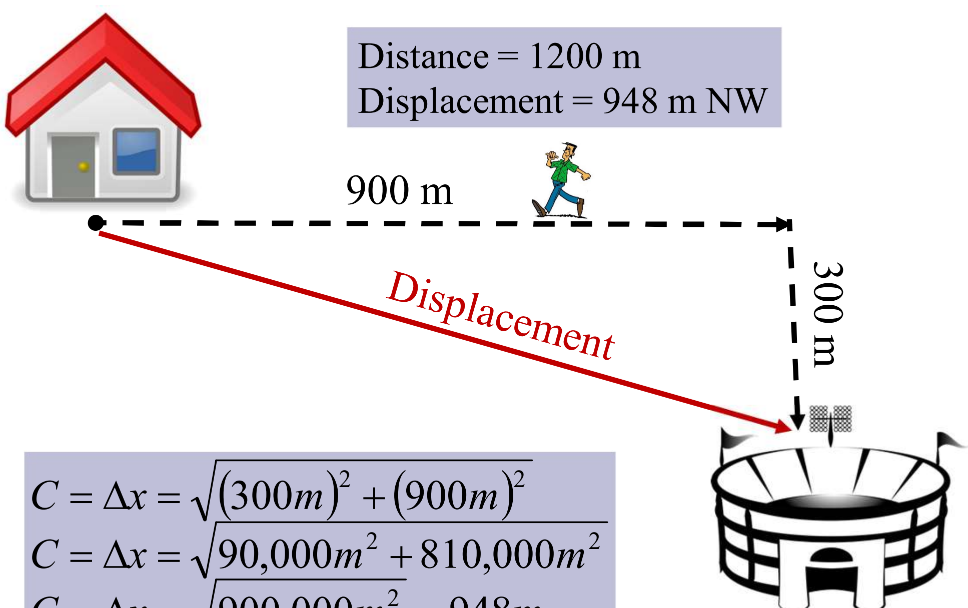
$$C = \sqrt{(400m)^2 + (300m)^2}$$
$$C = \sqrt{160{,}000m^2 + 90{,}000m^2}$$
$$C = \sqrt{250{,}000m^2} = 500m$$

Herman walks to the baseball stadium. He walks 900 m E, turns, walks 400 m S. Calculate his distance and displacement.



Calculate Herman's distance and displacement of his trip.

Distance = 1200 m
Displacement = 948 m NW



$$C = \Delta x = \sqrt{(300m)^2 + (900m)^2}$$
$$C = \Delta x = \sqrt{90{,}000m^2 + 810{,}000m^2}$$
$$C = \Delta x = \sqrt{900{,}000m^2} = 948m$$

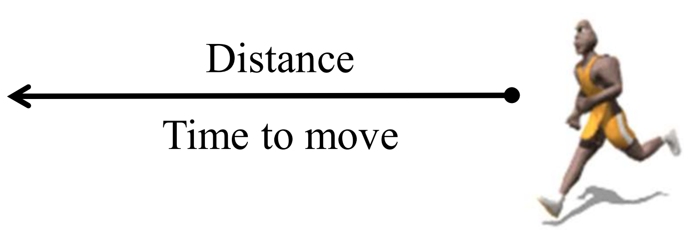
Speed & Velocity

How can we describe how "fast" something is moving?

Rate: change with time; "How fast" an object moves or changes position with time.

Motion

- **Change in position (moving a distance)**
- **Time to move**



Average Speed: (scalar) distance traveled per unit time.

- "How fast" something moves.
- Positive. Direction independent

$$v_{avg} = \frac{d}{t}$$

v_{avg} = average speed (m/s)
d = distance (m)
t = time (s)

Average Velocity: (vector) displacement per unit time.
Straight-line motion with direction.

- "How fast" in a straight line in one direction.
- Positive or negative because of direction.

$$\vec{v}_{avg} = \frac{\Delta x}{t}$$

$\vec{v}_{avg}$ = average velocity (m/s)
Δx = displacement (m)
t = time (s)

Note

- Generally, average speed ≠ magnitude of average velocity
  - Only when displacement equals distance

Steps to solving an average speed and velocity problem:

1. Calculate the total distance
2. Calculate the displacement
3. Calculate the total time of travel
4. Calculate the average speed (using distance)
5. Calculate the average velocity (using displacement)

A man runs a distance of 30 meters in 4 seconds. Solve for the man's average speed.

$$v = \frac{d}{t}$$

30 m

4 s

Use the problem solving steps.

A man runs a distance of **30 meters** in **4 seconds**. Solve for the man's average speed.

$$v = \frac{d}{t}$$

30 m

4 s

d = 30 m
t = 4 s

$$v = \frac{30m}{4s} = 7.5\,{}^{m}\!/_{s}$$

On the freeway, a car travels 100 m in 4.5 seconds.
Calculate the average speed of the car. Report in m/s

$$v = \frac{d}{t} \xleftarrow[4.5\ \text{s}]{100\ \text{m}}$$

On the freeway, a car travels 100 m in 4.5 seconds.
Calculate the average speed of the car. Report in m/s

$$v = \frac{d}{t} \xleftarrow[4.5\ \text{s}]{100\ \text{m}}$$

d = 100 m
t = 4.5 s

$$v = \frac{100m}{4.5s} = 22.2\,{}^{m}\!/_{s}$$

On the freeway, a car moves 200 m due east in 16.0 seconds. Calculate the average velocity of the car. Report in m/s.

$$\xrightarrow[\text{16.0 s}]{\text{200 m E}}$$

$$\vec{v} = \frac{\Delta x}{t}$$

On the freeway, a car moves 200 m due east in 16.0 seconds. Calculate the average velocity of the car. Report in m/s.

$$\xrightarrow[\text{16.0 s}]{\text{200 m E}}$$

$$\vec{v} = \frac{\Delta x}{t}$$

$\Delta x = 200$ m
t = 16 s

$$\vec{v} = \frac{200m}{16s} = 12.5 \, {}^{m}\!/_{s} \; E$$

Rearrange the speed or velocity equation to solve for distance or displacement ("how far").

$$d = v \cdot t \qquad \Delta x = \vec{v} \cdot t$$

Rearrange the speed or velocity equation to solve for time.

$$t = \frac{\Delta x}{v} \qquad t = \frac{\Delta x}{\vec{v}}$$

Solve for distance or travel time.

A car moves 300 meters at an average velocity of 18 m/s west. Calculate the time that the car was in motion.

A car moves 1000 meters at an average speed of 22 m/s. Calculate the time that the car was in motion.

A car moves with an average speed of 16 m/s. The car moves for 30 seconds. How far did the car travel?

A car moved **300 meters** at a velocity of **18 m/s west**. Calculate the time that the car was in motion. **(16.7 s)**

$$t = \frac{\Delta x}{\vec{v}} = \frac{300m}{18\,{}^{m}\!/\!{}_{s}} = 16.7s$$

A car moved **1000 meters** at a speed of **22 m/s**. Calculate the time that the car was in motion.

(45.4 s)

$$t = \frac{d}{v} = \frac{1000m}{22\,{}^{m}\!/\!{}_{s}} = 45.4s$$

A car moves with a speed of 16 m/s. The car moves for 30 seconds. How far did the car travel? **(480 m)**

$$d = v \cdot t$$
$$d = 16\,{}^{m}\!/\!{}_{s} \cdot 30s = 480m$$

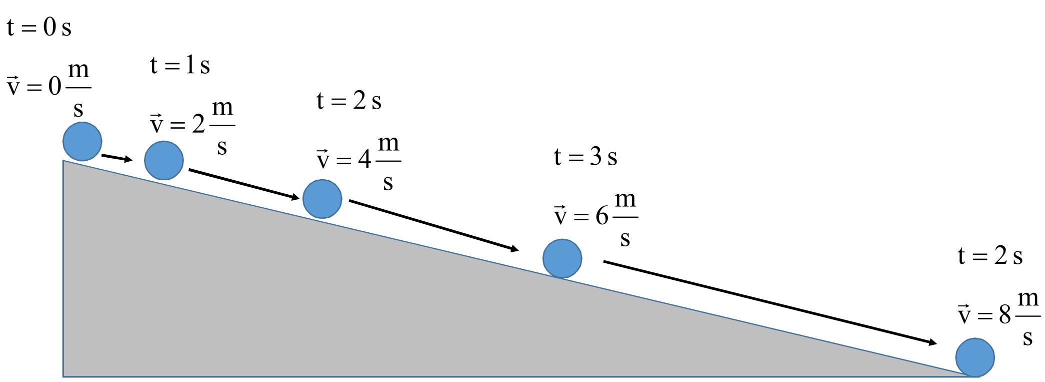
Average vs. Instantaneous Speed & Velocity

Instantaneous Speed: The speed of an object at any given moment in time. How fast at that given point in time.

Instantaneous Velocity: The velocity of an object at any given moment in time—instantaneous straight- line rate of motion.

Glance at a car's **speedometer** while the car is moving. You see the car's **instantaneous speed**.

Example: The ball rolls down the incline. It gets progressively faster with time.



The velocities are the INSTANTANEOUS VELOCITIES of the ball at each sequential second it moves.

Instantaneous vs. Average

Average speed & velocity are properties of the **whole** movement or trip of the object

Instantaneous speed & velocity are properties of **a particular moment in time**

Instantaneous vs. Average

Average speed & velocity:

- Generally, average speed ≠ magnitude of average velocity

Instantaneous speed & velocity:

- Instantaneous speed = magnitude of instantaneous velocity

Terminology

- The terms “velocity” and “speed” are generally used to refer to instantaneous velocity and instantaneous speed, not average velocity or average speed
- If we say just “velocity” or “speed,” we mean the instantaneous
- If we want to refer to average velocity or speed, we will explicitly mention that it is *average* velocity of speed

Equal Velocities

Since velocity is a vector, for two velocities to be equal they must have the same magnitude ***and*** the same direction

- If magnitudes are different: Different instantaneous speed and different instantaneous velocity.

25 m/s E and **30 m/s E** are different speeds and different velocities.

The magnitudes (how fast) are different.

- If magnitudes are the same, but directions are different: Equal instantaneous speed, different instantaneous velocity

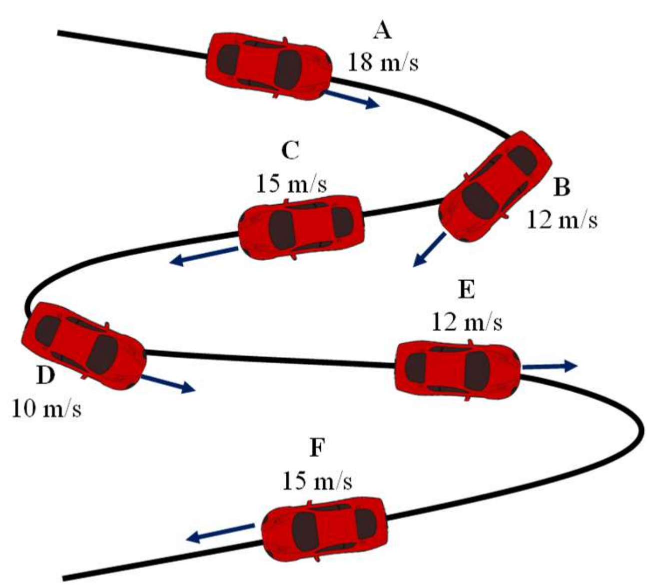
25 m/s E and **25 m/s S** are the same speeds but different velocities.

The magnitudes (how fast) are the same, but directions are different.

- If magnitudes and directions are the same: <u>Equal instantaneous velocity</u> (and equal instantaneous speed by default)

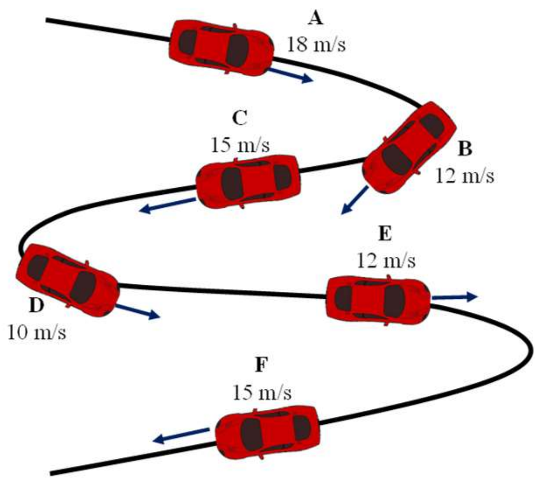
25 m/s E and **25 m/s E** are the same instantaneous speeds and velocities. Magnitudes and directions are the same.

A car moves around the curvy road. The numbers show how fast the car is moving at positions A, B, C, D, E, and F.



Equal instantaneous speed
B & E 12 m/s
C & F 15 m/s
Same "how fast"

Equal instantaneous velocity
C & F 15 m/s SW
Same "how fast" &
same direction



Resultant Velocity

Resultant Velocity

When the environment in which an object moves is also moving, the overall, or **resultant**, velocity of the object will be altered

Examples:

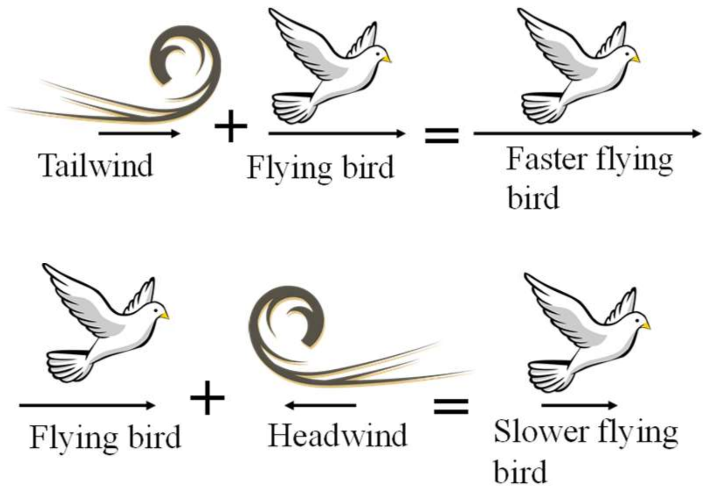
- Bird flying in wind
- Boat crossing a flowing river

Resultant Velocity

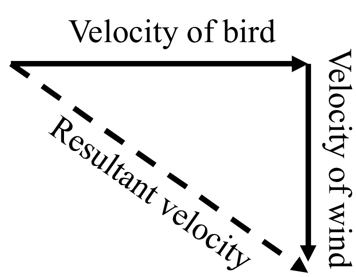
The resultant velocity is just the vector sum of the object's velocity and the velocity of the environment:

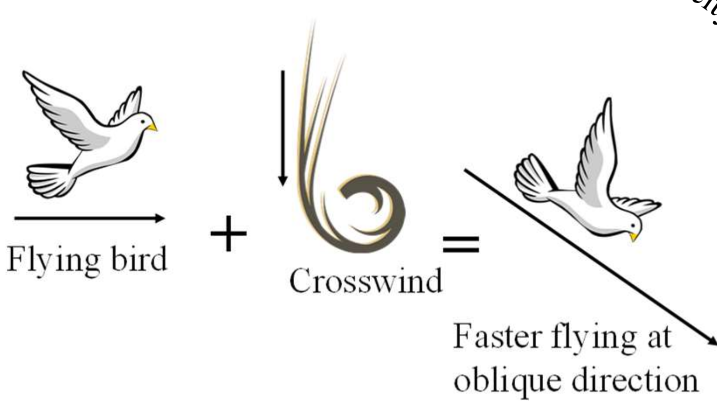
$$\vec{v}_{resultant} = \vec{v}_{object} + \vec{v}_{environment}$$

If the interacting velocities are in **1-dimension** (N-S, E-W, U-D, or L-R), add the vectors together using the + and – for directions.



If the interacting velocities are at right angles, use the Pythagorean theorem to solve for the resultant velocity





Acceleration

How do we describe how an object's velocity changes?

What is acceleration?

- The change in velocity per unit of time
- How the velocity changes with each second
- Caused by forces (more about this in Unit 2)

- Unit: $\frac{m}{s^2}$
  - "Meters per second, per second" or "meters per second squared"

What is acceleration?

- Acceleration is a vector quantity
  - Has magnitude and direction

<u>Example</u>

5 m/s^2 North

- Means 5 m/s N is added to the velocity every second

Calculating Acceleration

$$\vec{a} = \frac{\Delta\vec{v}}{t} = \frac{\vec{v}_f - \vec{v}_i}{t}$$

Example

- A car is waiting at a stoplight. At time zero, the light turns green. Ten seconds later, the car is moving at 27 m/s W. What was the car's acceleration?

Four Forms of Acceleration

As a vector, velocity can change in four ways. Therefore, there are four ways that an object can accelerate:

1. The speed increases (magnitude of velocity increases)
2. The speed decreases (magnitude of velocity decreases)
3. The direction changes (direction of velocity changes)
4. The combination of a change in speed and direction

One-Dimensional Motion

- Magnitude is the number
- Direction is the sign (+ or -)

Example

+5 m/s Speed = Direction =

-5 m/s Speed = Direction =

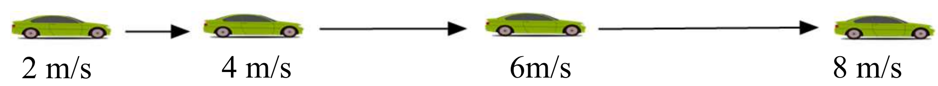
- **When *a* and *v* are in *same* direction, speed *increases***
  - A (+) velocity becomes a larger (+) number
  - A (-) velocity becomes a more (-) number
- **When *a* and *v* are in *opposite* directions, speed *decreases***
  - A (+) velocity becomes a smaller (+) number
  - A (-) velocity becomes a less (-) number

Velocity and Acceleration

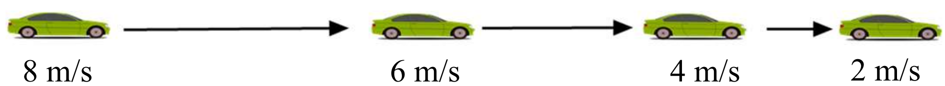
v_i	a	Motion
+	+	speeding up
–	–	speeding up
+	–	slowing down
–	+	slowing down
– or +	0	constant velocity
0	– or +	speeding up from rest
0	0	remaining at rest

If the object's **velocity is not changing** (constant velocity), **acceleration is ZERO**

If the object **is getting faster** (speeding up), acceleration is **in the same direction as the object's motion.**



If the object **is getting slower** (slowing down), acceleration is **in opposite direction of the object's motion.**



Identify the direction of the acceleration.

- Car's velocity 0 m/s to 20 m/s north.
- Car's velocity -5 m/s to -20 m/s south.
- Car's velocity -25 m/s to -10 m/s west.
- Car's velocity 25 m/s to 25 m/s east
- Car's velocity 30 m/s to 0 m/s east
- Car's velocity 15 m/s to 15 m/s north
- Car's velocity -10 m/s to -30 m/s west

Identify the direction of the acceleration.

- Car’s velocity 0 m/s to 20 m/s north. **(NORTH)**
- Car’s velocity -5 m/s to -20 m/s south. **(SOUTH)**
- Car’s velocity -25 m/s to -10 m/s west. **(EAST)**
- Car’s velocity 25 m/s to 25 m/s east **(ZERO)**
- Car’s velocity 30 m/s to 0 m/s east **(WEST)**
- Car’s velocity 15 m/s to 15 m/s north **(ZERO)**
- Car’s velocity -10 m/s to -30 m/s west **(WEST)**

Kinematic Equations

Kinematic Equations

Equations that express the relationships between five variables:

- Initial velocity ($\overrightarrow{v_i}$)
- Final velocity ($\overrightarrow{v_f}$)
- Time (t)
- Displacement (Δx)
- Acceleration ($\vec{a}$)

IMPORTANT: The equations are **ONLY** true for uniform (constant) acceleration

$$\vec{v}_f = \vec{v}_i + \vec{a}t$$

$$\Delta x = \vec{v}_i t + \frac{1}{2}\vec{a}t^2$$

$$\vec{v}_f^2 = \vec{v}_i^2 + 2\vec{a}(\Delta x)$$

$$\vec{v}_f = \vec{v}_i + \vec{a}t$$

$$\vec{a} = \frac{\vec{v}_f - \vec{v}_i}{t}$$

$$\Delta x = \vec{v}_i t + \frac{1}{2}\vec{a}t^2$$

$$\vec{a} = \frac{2(\Delta x - \vec{v}_i t)}{t^2}$$

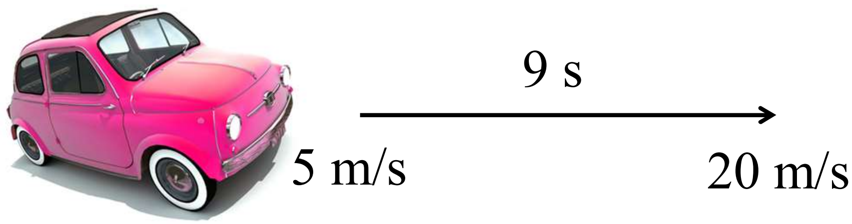
$$\vec{v}_f^2 = \vec{v}_i^2 + 2\vec{a}(\Delta x)$$

Problem-Solving Strategy

1. Write the given information
2. Write the unknown you are trying to find
3. Draw a sketch of the scenario (if applicable)
4. Choose an equation and rearrange it if needed
5. Plug in the given values in the equation and solve for the unknown

A car is moving at an initial velocity of **5.0 m/s**. The car accelerates to **20 m/s** in **9 seconds**.

- **Calculate the acceleration of the car.**
- **Calculate how far the car moved as it accelerated.**



A car is moving at an initial velocity of **5.0 m/s**. The car accelerates to **20 m/s** in **9 seconds**.

- **Calculate the acceleration of the car.** **(1.67 m/s²)**
- **Calculate how far the car moved as it accelerated.**

(112.6 m)

$$\vec{a} = \frac{\Delta \vec{v}}{t} = \frac{20\frac{m}{s} - 5.0\frac{m}{s}}{9s} = 1.67\, {}^{m}\!/\!{}_{s}$$

$$\Delta x = (v_0 \cdot t) + \left(\frac{1}{2} \cdot \vec{a} \cdot t^2\right) = \left(5.0\frac{m}{s} \cdot 9s\right) + \left(\frac{1}{2} \cdot 1.67\frac{m}{s^2} \cdot (9s)^2\right)$$

$$\Delta x = 45m + 67.6m = 112.6m$$

A car on the freeway slows from 30 m/s to 20 m/s in 15 seconds.

- **Calculate the acceleration of the car.**
- **Calculate how far the car moved as it accelerated**

15 s

30 m/s

20 m/s

A car on the freeway slows from 30 m/s to 20 m/s in 15 seconds.

- **Calculate the acceleration of the car.** **(-0.667 m/s²)**
- **Calculate how far the car moved as it accelerated.**

(375 m)

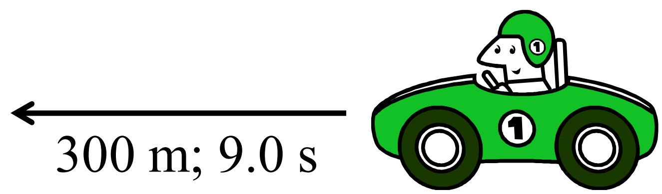
$$\vec{a} = \frac{\Delta\vec{v}}{t} = \frac{20\frac{m}{s} - 30\frac{m}{s}}{15s} = -0.667\, {}^{m}\!/_{s}$$

$$\Delta x = (v_0 \cdot t) + \left(\frac{1}{2}\cdot\vec{a}\cdot t^2\right) = \left(30\frac{m}{s}\cdot 15s\right) + \left(\frac{1}{2}\cdot -0.667\frac{m}{s^2}\cdot(15s)^2\right)$$

$$\Delta x = 450m + -75.0m = 375m$$

From a **stop**, the racecar accelerates over a distance of **300 meters** in **9 seconds**.

- Calculate the acceleration of the car.
- Calculate how fast was it moving after it accelerated.



From a **stop**, the racecar accelerates over a distance of **300 meters** in **9 seconds**.

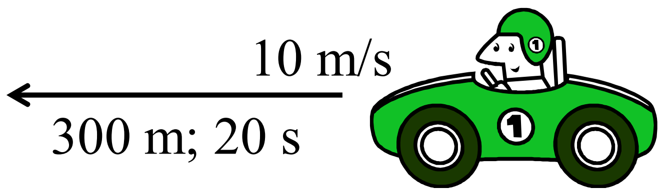
- **Calculate the acceleration of the car.** **(7.41 m/s²)**
- **Calculate how fast was it moving after it accelerated.**

(66.7 m/s)

$$\vec{a} = \frac{2\cdot(\Delta x - \vec{v}_0 \cdot t)}{t^2} = \frac{2\cdot\left(300m - \left(0\frac{m}{s}\cdot 9s\right)\right)}{(9s)^2} = 7.41 \, {}^{m}\!/_{s^2}$$

$$\vec{v}_f = \vec{v}_0 + a\cdot t = 0\frac{m}{s} + \left(7.41\frac{m}{s^2}\cdot 9s\right) = 66.7 \, {}^{m}\!/_{s}$$

From an initial velocity of **10 m/s**, the racecar accelerates over a distance of **300 meters** in **20 seconds**.
- Calculate the acceleration of the car.
- Calculate how fast was the car moving after it accelerated.



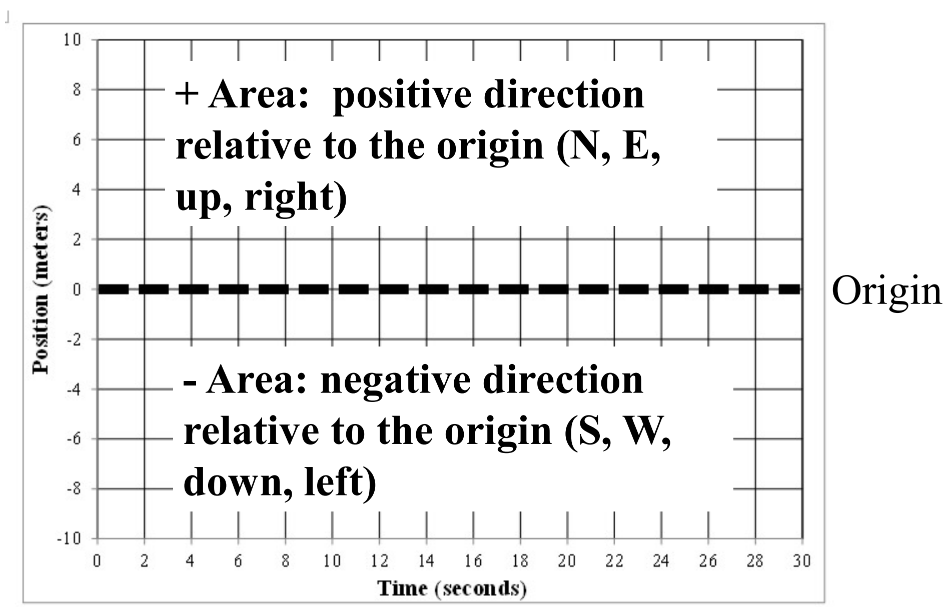
From an initial velocity of **10 m/s**, the racecar accelerates over a distance of **300 meters** in **20 seconds**.
- Calculate the acceleration of the car.
- Calculate how fast was the car moving after it accelerated.

$$\vec{a} = \frac{2\cdot\left(\Delta x - \vec{v}_0 \cdot t\right)}{t^2} = \frac{2\cdot\left(300m - \left(10\frac{m}{s}\cdot 20s\right)\right)}{\left(20s\right)^2} = 0.500\,{}^{m}\!/_{s^2}$$

$$\vec{v}_f = \vec{v}_0 + a\cdot t = 10\frac{m}{s} + \left(0.500\frac{m}{s^2}\cdot 20s\right) = 20\,{}^{m}\!/_{s}$$

Motion Graphs: Position vs. Time

How do we represent motion using a graph?



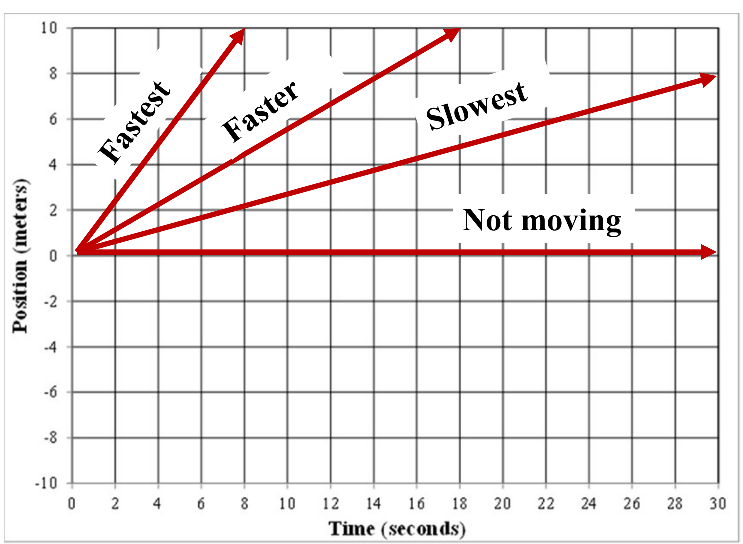
Slopes tell us how fast the object moves (change in position with time).

Calculate the slope = velocity of the moving object.

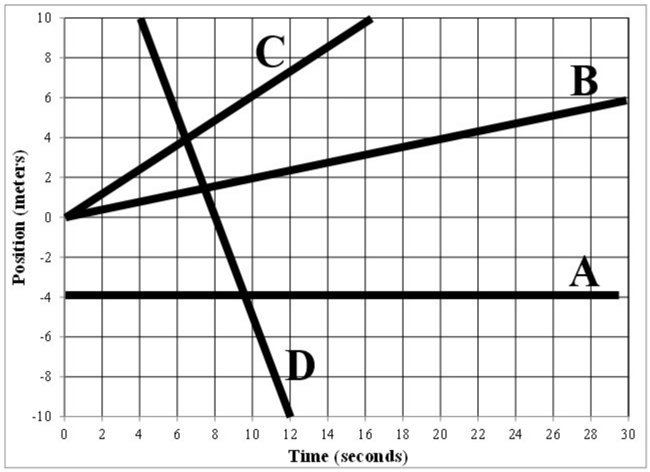
Slope of zero (horizontal line) = no motion. Velocity is 0 m/s

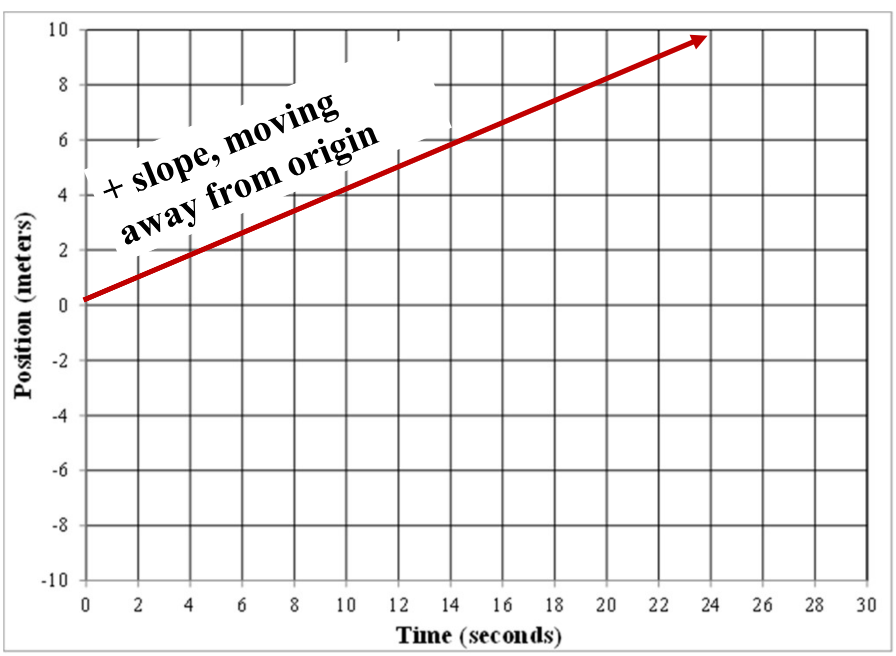
- **Lower slope = slower moving**
- **Steep slope = faster moving**

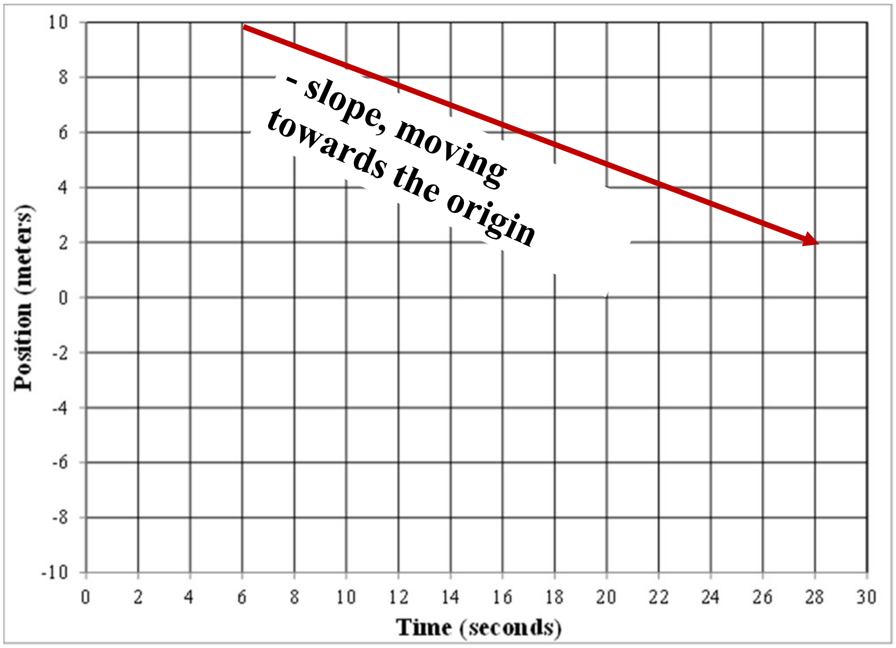
Slopes of line = velocity ("how fast" object moves

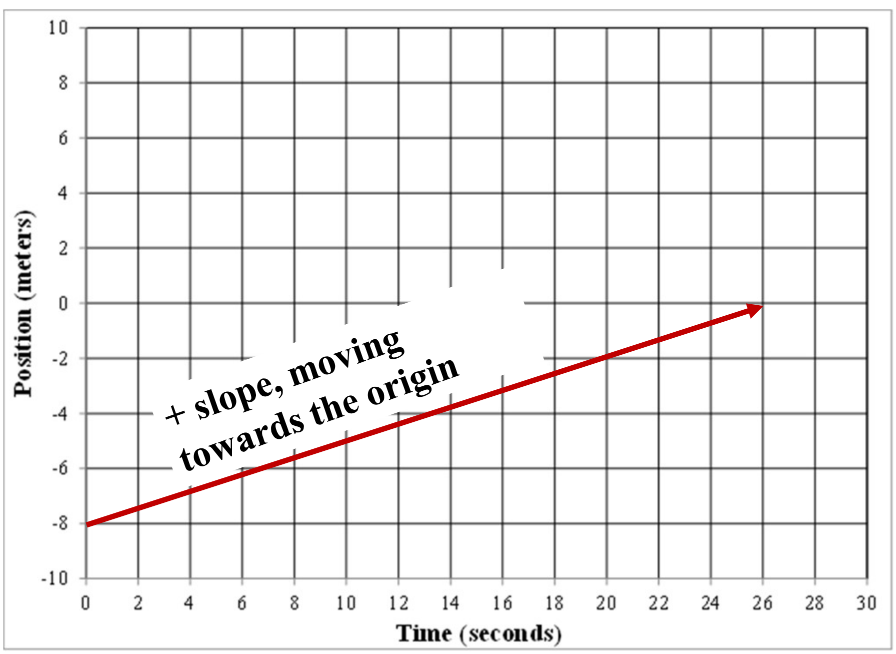


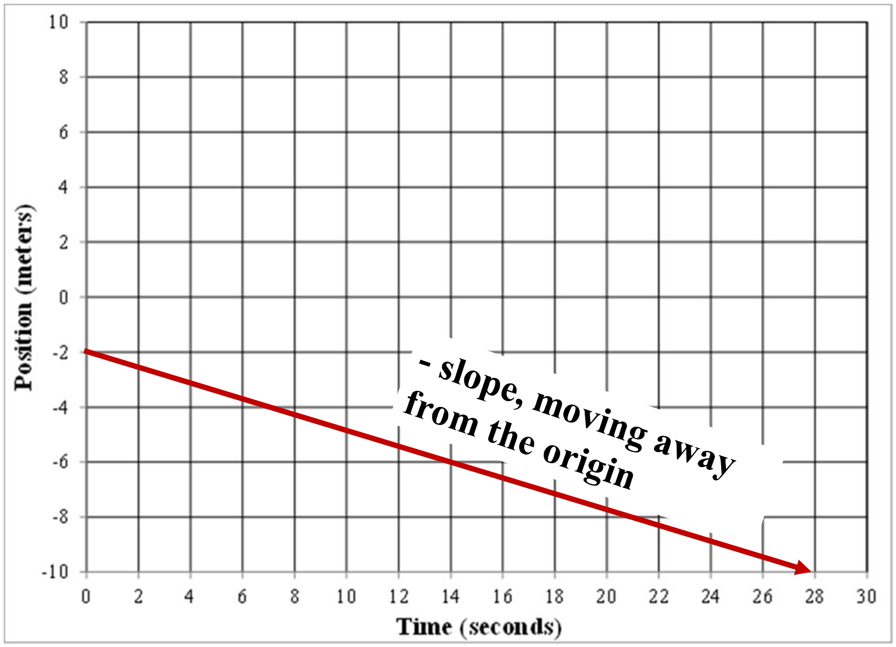
A is motionless: v = 0 m/s (slope of zero)
B is moving slow: v = 0.20 m/s (least steep)
C is moving faster v = 0.62 m/s
D is moving fastest: v = -2.5 m/s (steepest)



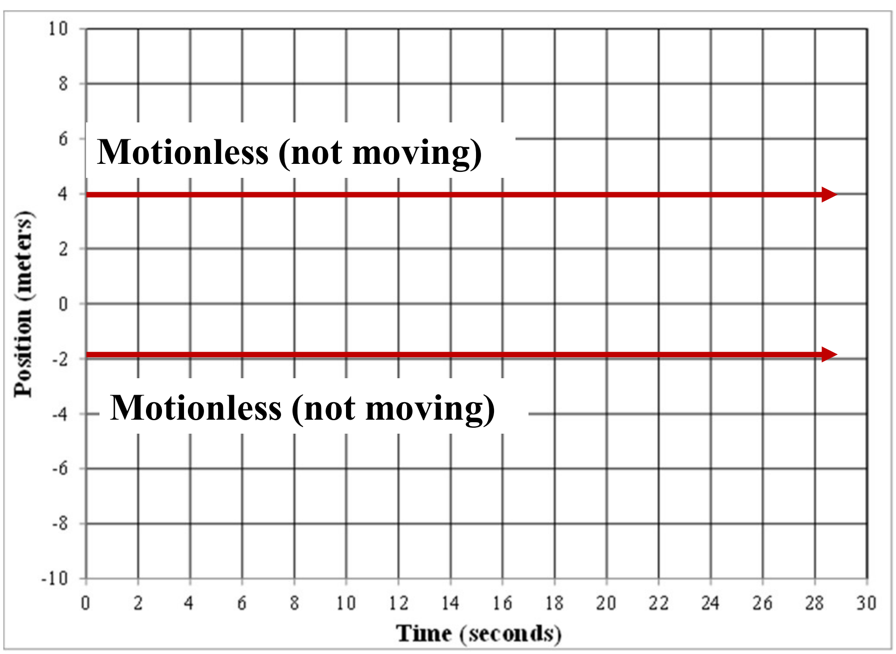



- slope, moving towards the origin
Position (meters)
Time (seconds)

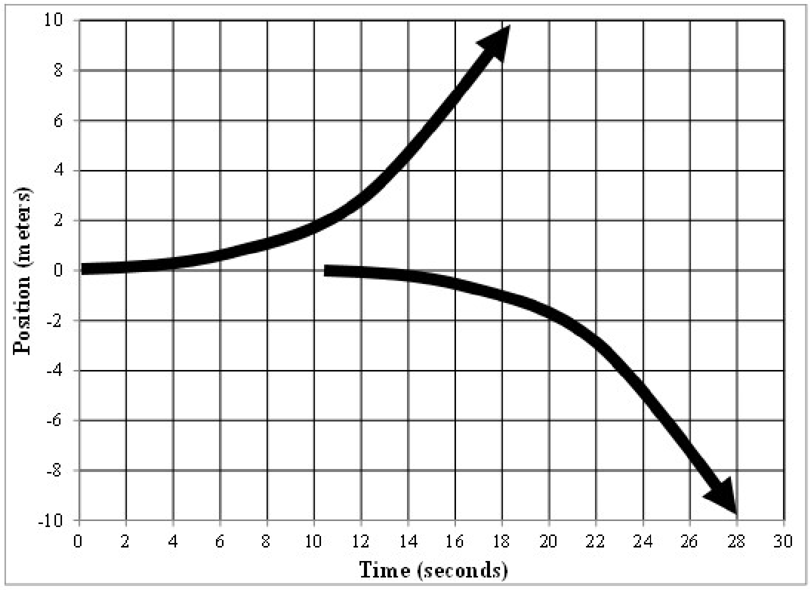

+ slope, moving towards the origin
Position (meters)
Time (seconds)



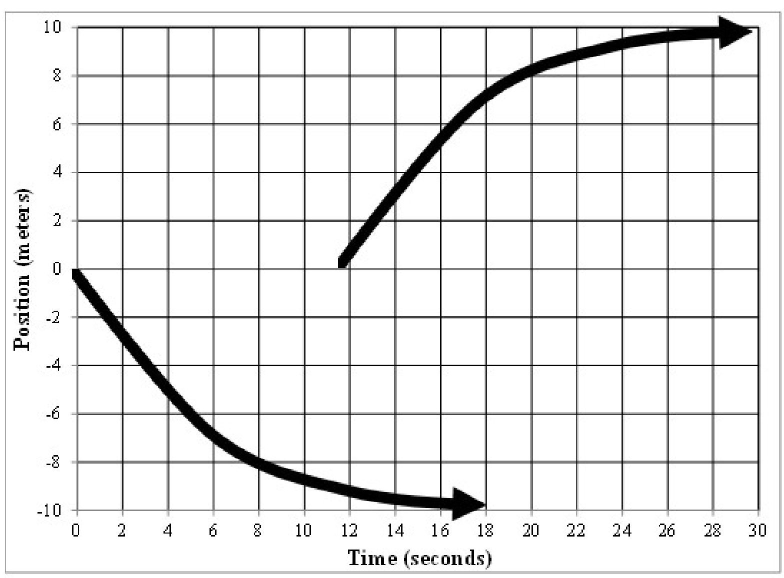
Position (meters)
Time (seconds)
- slope, moving away from the origin



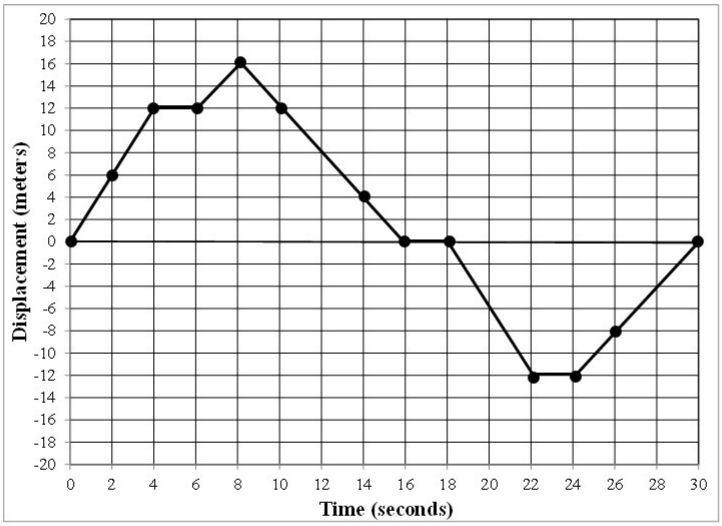
Position (meters)
Time (seconds)
Motionless (not moving)
Motionless (not moving)



Getting faster with time, increasing speed
Gentle slope to steeper slope



Getting slower with time, decreasing speed
Steeper slope to more gentle slope



Distance = how far object moves (add together the segments of travel). Displacement = how far from start, straight-line change in position.