Motion

Chapter 12.1 and 11

What Produces Motion?

WARM-UP

THINK ABOUT IT

1. Place two coins of different size (quarter, nickel, dime, penny) on the table in front of you. Do they move on their own? What is required?

2. Put your finger on the larger coin and push it into a stationary smaller coin. What happens to the smaller coin?

3. Push the larger coin into the smaller coin again, observing how far it travels when hitting the smaller coin softly versus hitting it harder. How is the distance traveled by the smaller coin affected when you hit it harder?

4. State a relationship concerning the force with which something is hit and its motion?

What Produces Motion?

WARM-UP

THINK ABOUT IT

1. Place two coins of different size (quarter, nickel, dime, penny) on the table in front of you. Do they move on their own? What is required?
   The coins have to be pushed in order to move. (some kind of FORCE)

2. Put your finger on the larger coin and push it into a stationary smaller coin. What happens to the smaller coin?
   The larger coin stops (because it has more mass) and the smaller coin travels a certain distance (because momentum is transferred).

3. Push the larger coin into the smaller coin again, observing how far it travels when hitting the smaller coin softly versus hitting it harder. How is the distance traveled by the smaller coin affected when you hit it harder?
   The more Force (the harder you hit the smaller coin) the farther it travels.

4. State a relationship concerning the force with which something is hit and its motion?
   Direct relationship … Greater the force, Greater the motion.

Focus Questions

1. Describe how motion is produced.
2. Explain what is meant by relative motion and factors involved.
3. Distinguish between speed and velocity and know how to calculate both. Describe the types of speed and velocity.
4. Define and calculate acceleration, acceleration due to gravity, and free fall.

Mechanics

- Mechanics is the study of energy that creates forces and produces motion.
- There are TWO general types of energy:
  - KE → kinetic energy (energy of motion)
  - PE → potential energy (stored energy)
- Every force is based on one or both of the types of energy (KE and/or PE)
- Forces produce motion and the ultimate and original "Mover" is God.

Relative Motion

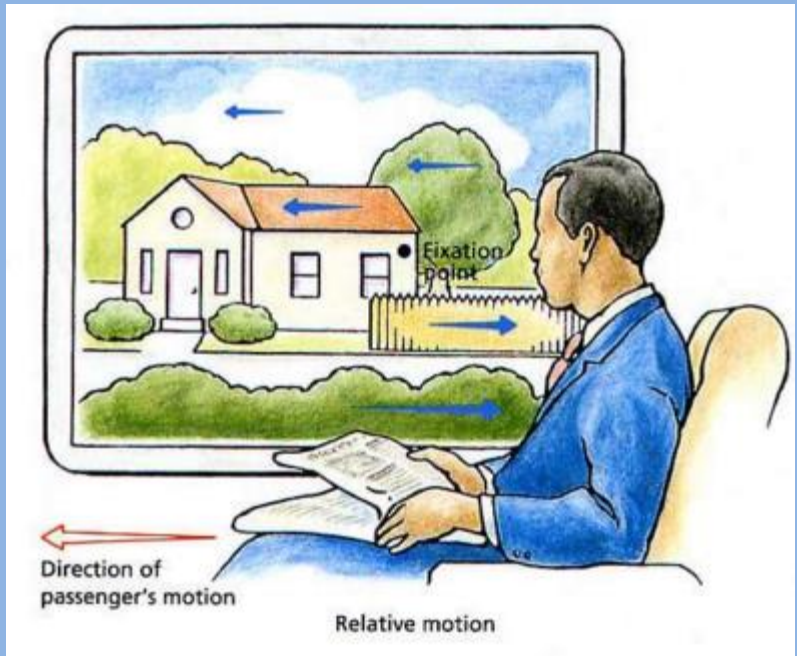
Motion is always relative to POSITION

The most basic motion (speed) is described as "position versus time" or "displacement"

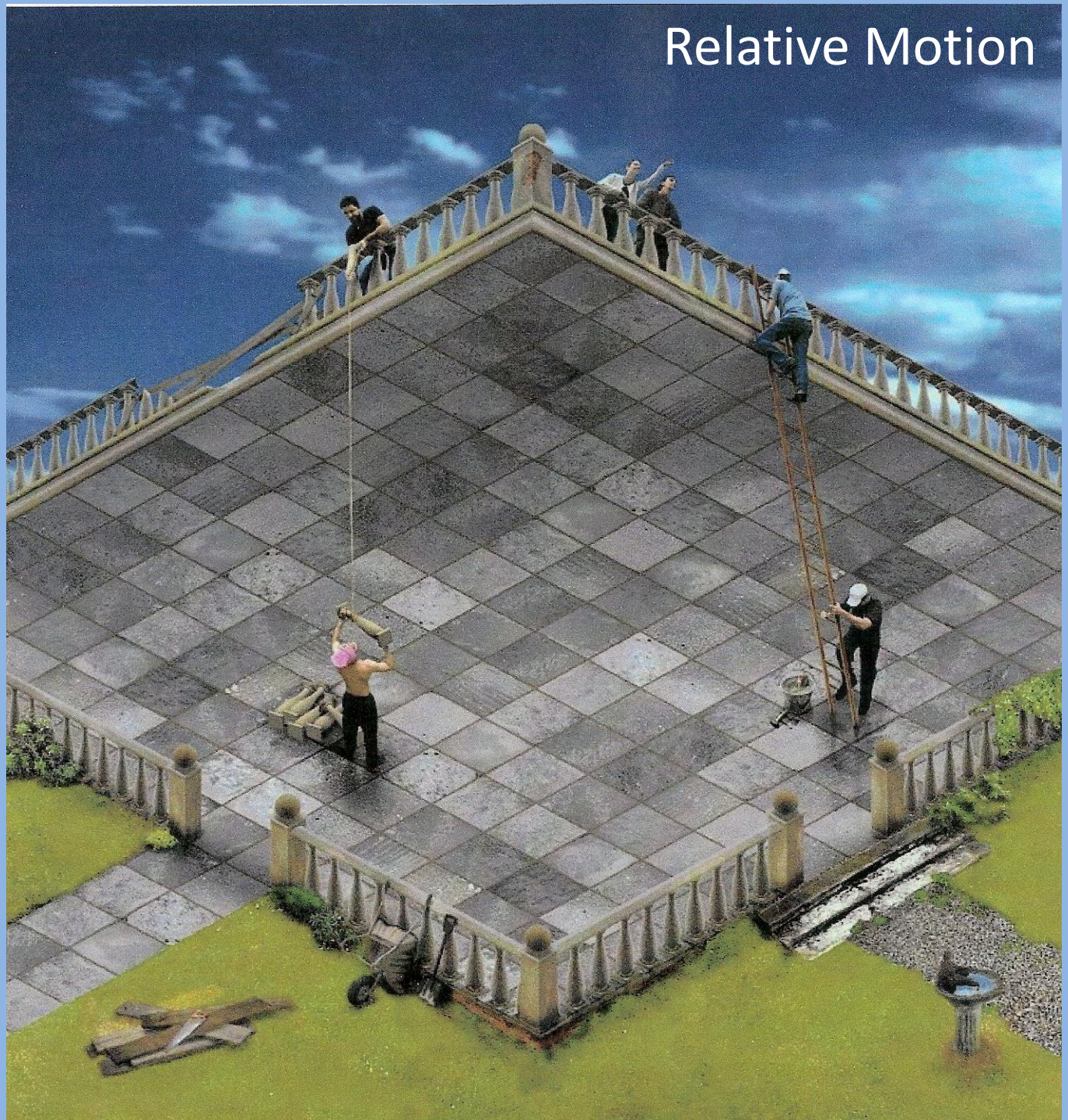
Every position has a "Reference Point"

- **A point against which position is measured**

All motion is relative – motion depends on the reference point that is used.



Relative Motion



Relative Motion Animations

http://somup.com/cFXhD1n144

(Car driving through a snow storm) (0:32)

http://somup.com/cFXhDQn14A

(boy on train platform) (0:55)

Bugs & Daffy and the Beanstalk [6:53]

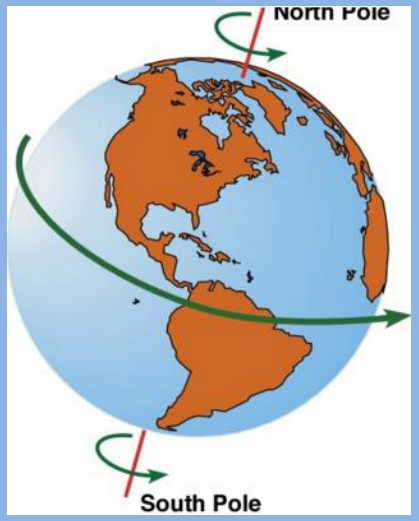
http://somup.com/cFXhoMn14r

Relative Motion

You are sitting in a car … how fast are you moving?

How fast is the car moving?

But what about from outer space?



Relative Motion

You are sitting in a car … how fast are you moving?

in relation to the car: 0 mph

How fast is the car moving?

in relation to the road:

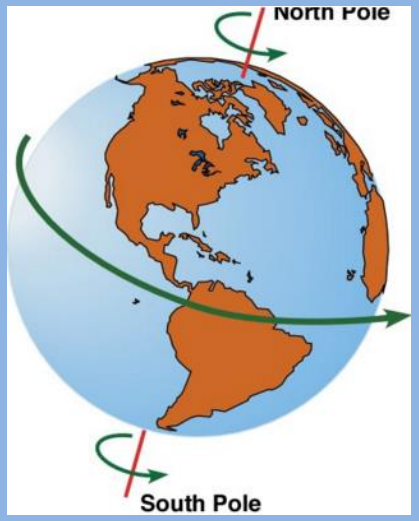
64 mph

But what about from outer space?

in relation to outer space:

Going West: ~936 mph

Going East: ~1064 mph



Forces Produce Motion

A **force** is a push or pull.

A force may give energy to an object, setting the object in motion, stopping it, or changing its direction.

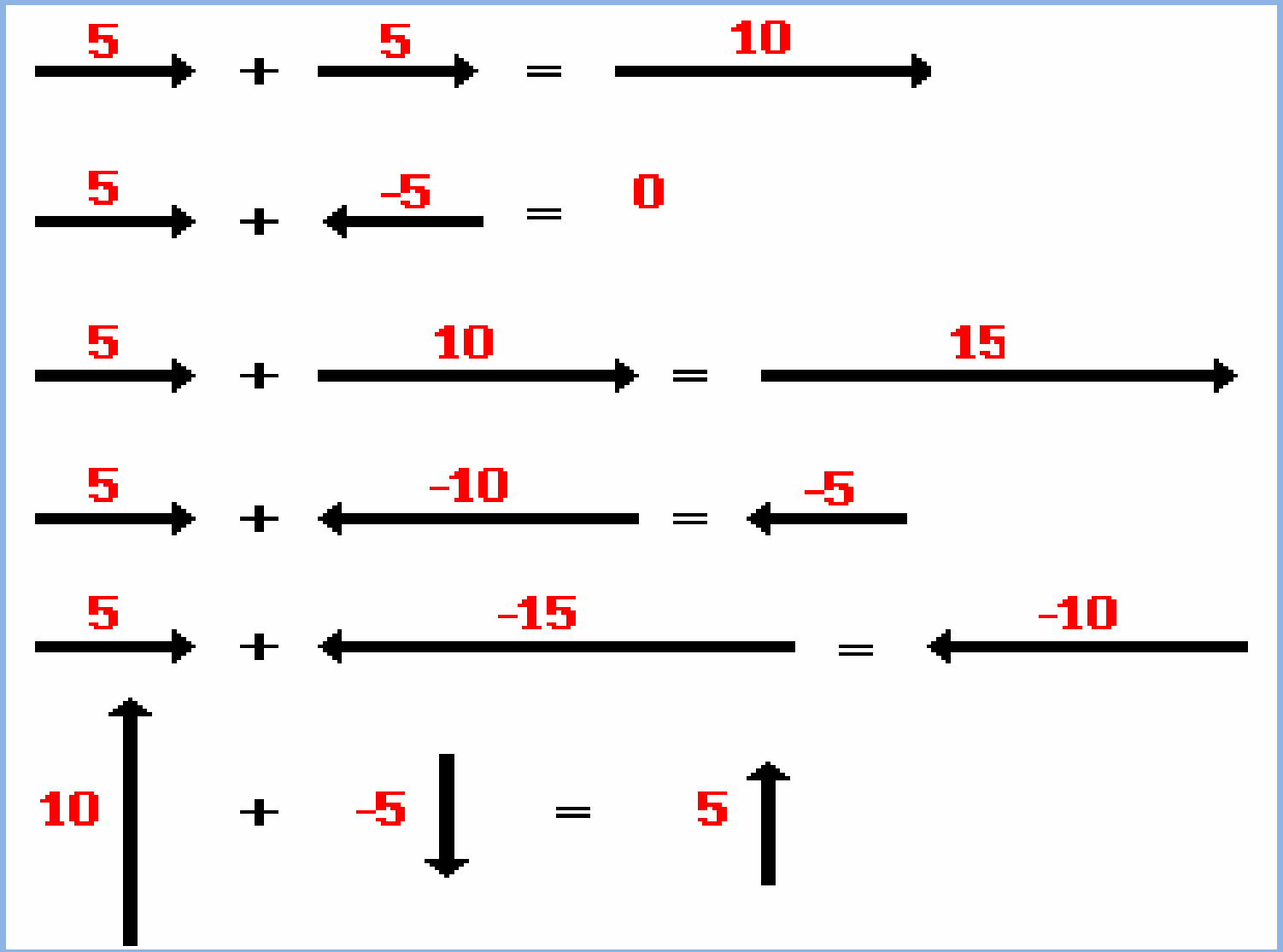
Force & motion are in the same direction.

Balanced forces are opposite in direction and equal in size. Motion can be sustained by balanced forces, called constant motion.

Unbalanced forces cause a **change** in motion. When forces are balanced, there is no change in motion.

NET Force

The sum of all the **forces** that act upon an object.



NET Force

Forces in the same direction combine by addition.

These are "UNbalanced" forces

Forces in opposite directions combine by subtraction.

Balanced forces cancel each other out. E.g. Tug-O-War

These are equal & opposite forces

Forces Produce Motion

Balanced forces

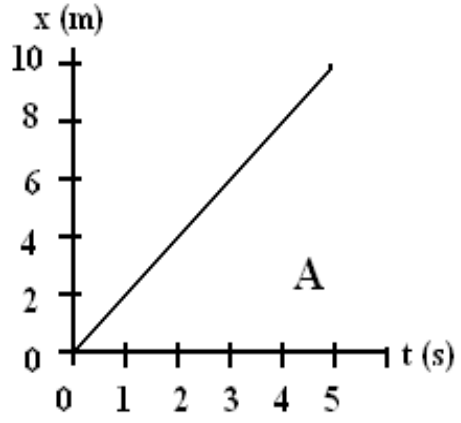
- are opposite in direction and equal in size.
- Motion can be sustained by balanced forces, called constant motion.
- Net force = 0.
- *When forces are balanced, there is no change in motion.*

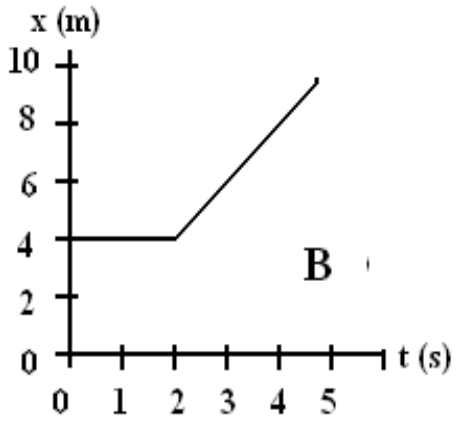
Unbalanced forces

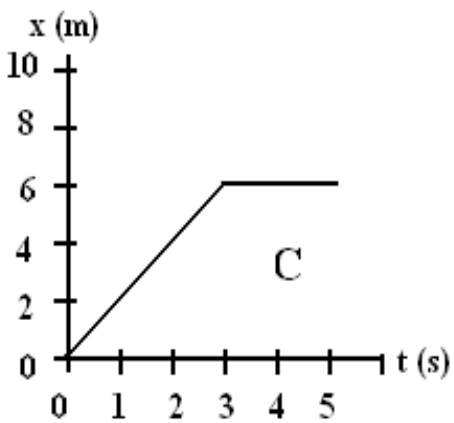
- cause a **change** in motion.
- Produce a "Net force" in some direction.

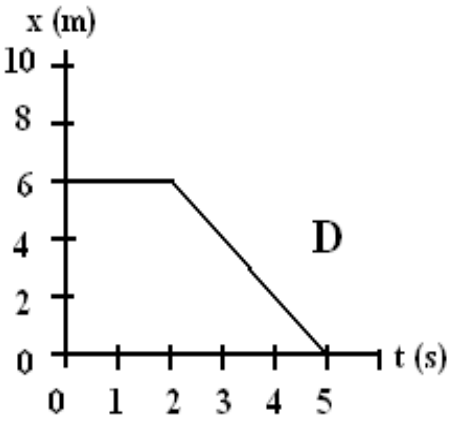
Position Versus Time - Displacement

Consider & Describe the motion represented by each "Position – Time" graph below.

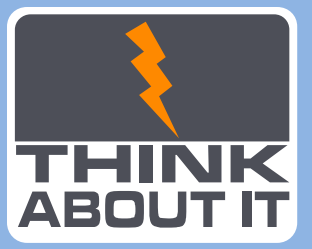






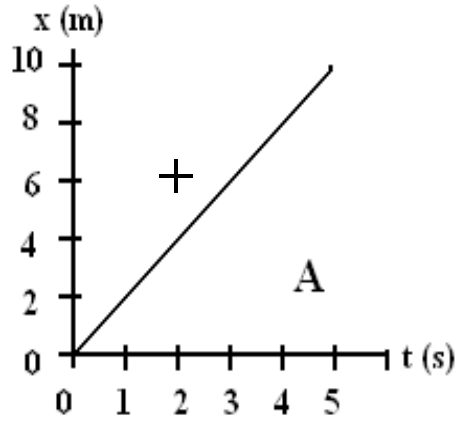


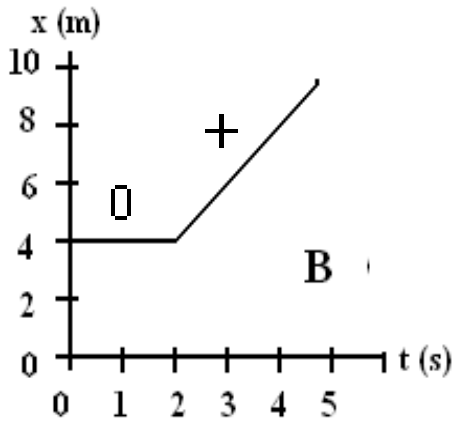
Imagine yourself standing and moving forward or backward based on each graph.

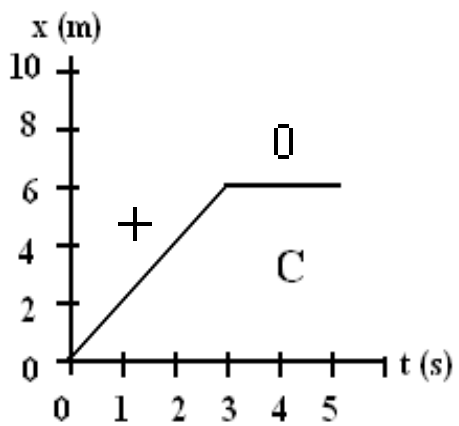


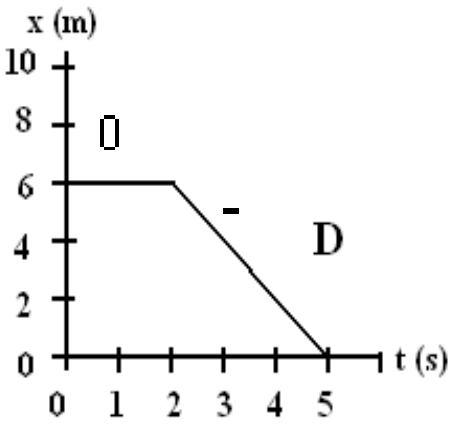
Position Versus Time - Displacement

Consider & Describe the motion represented by each "Position – Time" graph.









A → moving in a positive direction for 5 seconds

B → stopped (standing still) for two seconds, then moving in a positive direction for 3 seconds

C → moving in a positive direction for 3 seconds, then stopped (standing still) for 2 seconds

D → stopped (standing still) for two seconds, then moving in a negative direction (backwards) for 3 seconds

Vector quantities

Definition of a Vector

- A vector is comprised of (1) a number (magnitude) WITH (2) a direction.
- Examples:

3 km east	145 mph west
13 steps forward	67 paces sideways
9000 N up	2.5 g towards earth

- A vector ALWAYS has a magnitude (*with units*) and a direction that defines it. A "scalar" quantity only includes magnitude (*with units*).

Vector Quantity	Non-Vector Quantity
Displacement	Distance
Velocity	Speed
Acceleration	
Force	

Displacement (vs. distance)

A soccer player runs forward a distance of 4 m, reverses direction and runs a distance of 3 m, and then reverses direction once more for a distance of 8 m. How far did the person run?

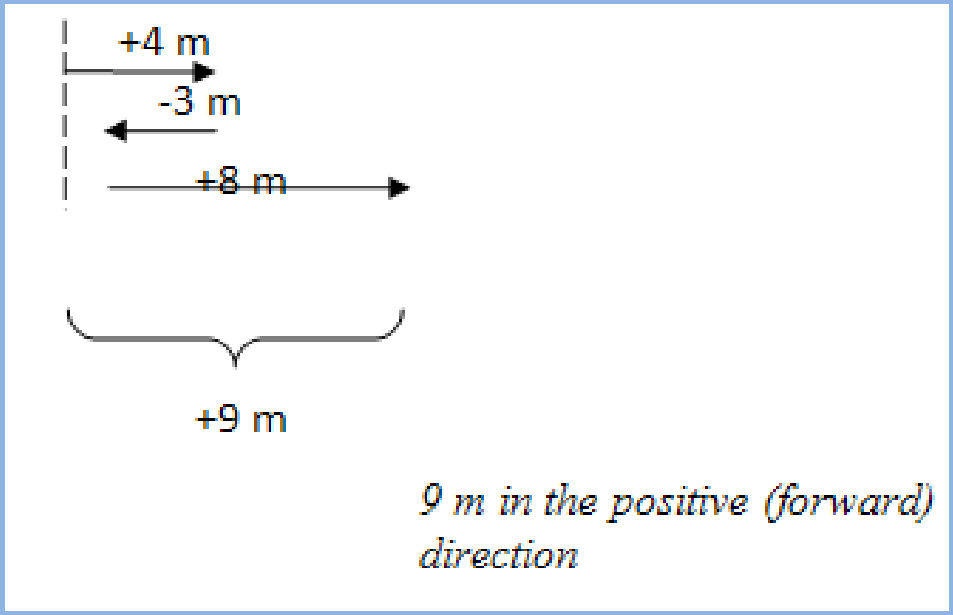
What is the person's displacement?

Displacement (vs. distance)

A soccer player runs forward a distance of 4 m, reverses direction and runs a distance of 3 m, and then reverses direction once more for a distance of 8 m. How far did the person run?

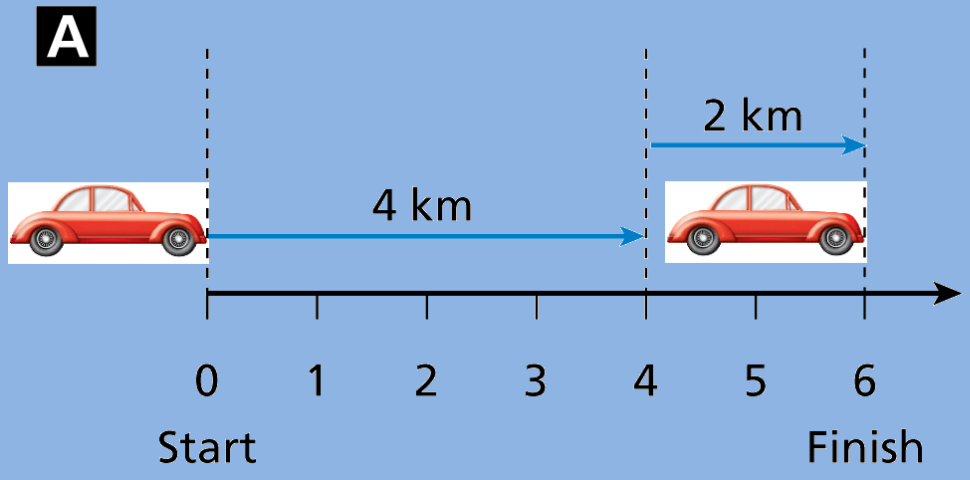
4 m + 3 m + 8 m = 15 m

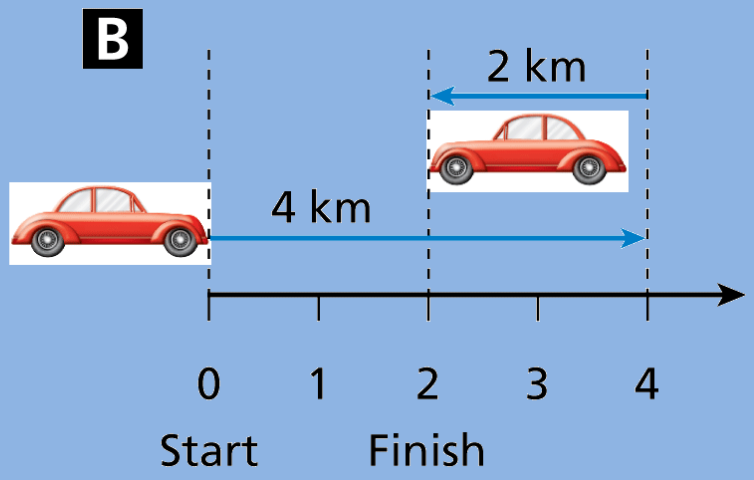
What is the person's displacement?



Displacement (vs. distance)

What is the distance travelled and the displacement?





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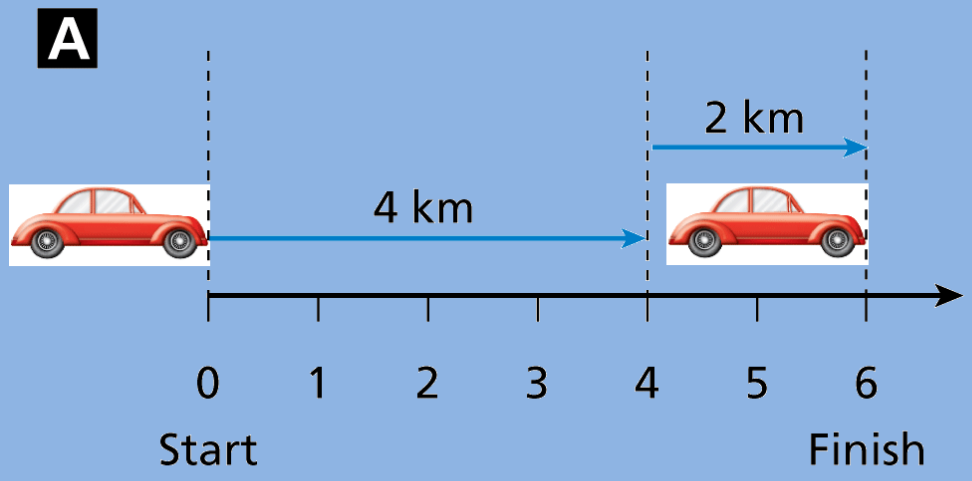
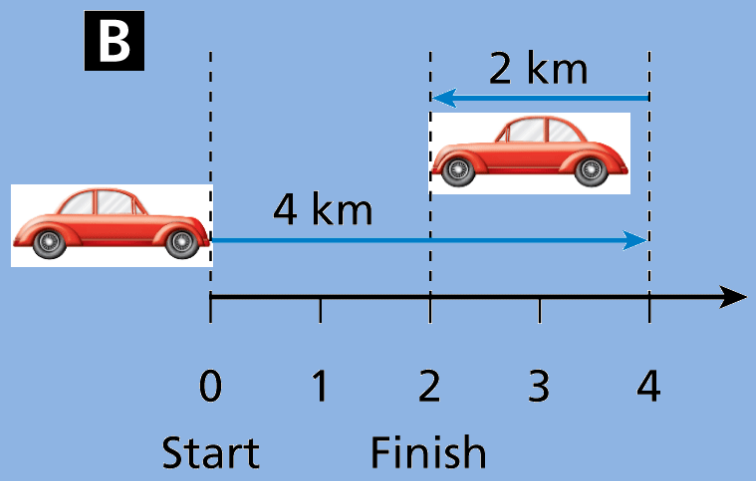




A Distance travelled = 6 km

Displacement = 6 km forward

B Distance travelled = 6 km

Displacement = 2 km forward

Speed

Force produces motion and this relates to speed

- Imagine a student standing on the skateboard without moving (*What kind of force?)*

- Imagine another student pushing the skateboarder (*What kind of force?)*
- Will he/she move indefinitely (*Why or why not?)*

Speed

Force produces motion and this relates to speed

- Imagine a student standing on the skateboard without moving (*What kind of force?)*
  - *Balanced … no change in motion*
- Imagine another student pushing the skateboarder (*What kind of force?)*
  - *Unbalanced … a NET force changes motion*
- Will he/she move indefinitely (*Why or why not?)*
  - *No, friction forces will slow them down*

Speed

Let's pretend that the skateboarder was timed over specific distances as follows:

	Trial 1	Trial 2	Trial 3	Totals
Distance (m)	4 m	8 m	12 m	
Time (s)	1 s	2 s	3 s	
Speed (d/t)				Avg:

Speed = distance / time

Speed

Let's pretend that the skateboarder was timed over specific distances as follows:

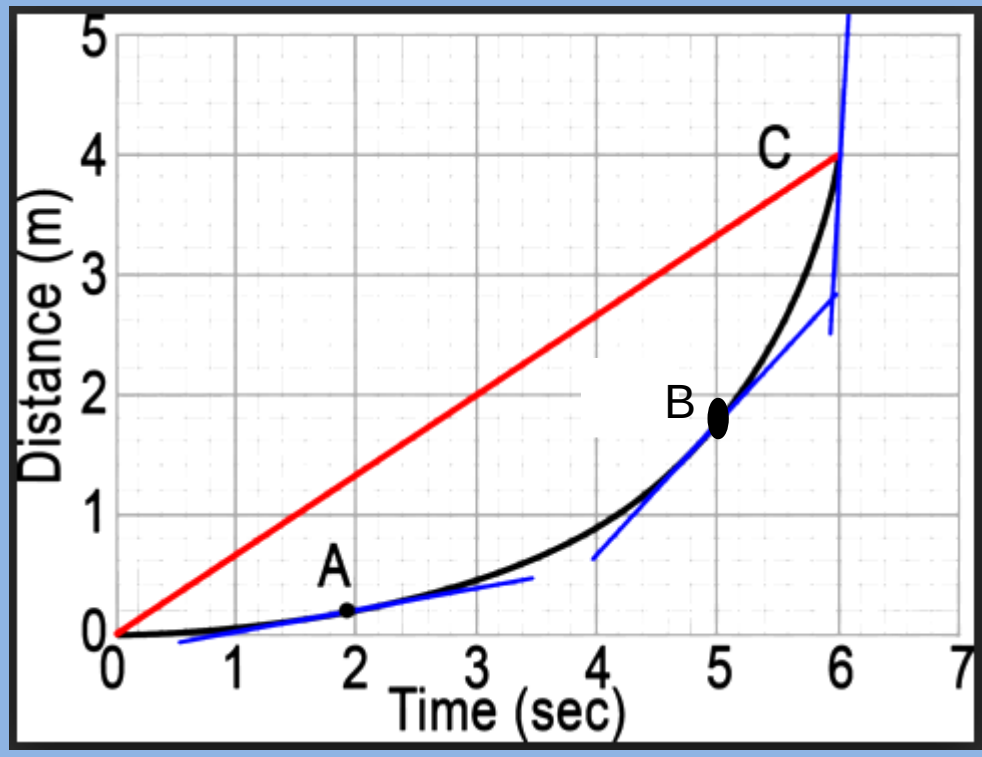
	Trial 1	Trial 2	Trial 3	Totals
Distance (m)	4 m	8 m	12 m	24 m
Time (s)	1 s	2 s	3 s	6 s
Speed (d/t)	4 m/s	4 m/s	4 m/s	Avg: 4 m/s

Speed = distance / time

Types of Speed

INSTANTANEOUS speed

– speed at a given moment of time



Speed at Point A.

0.2 m / 1.9 s = 0.1 m/s

Speed at Point B.

1.8 m / 5 s = 0.36 m/s

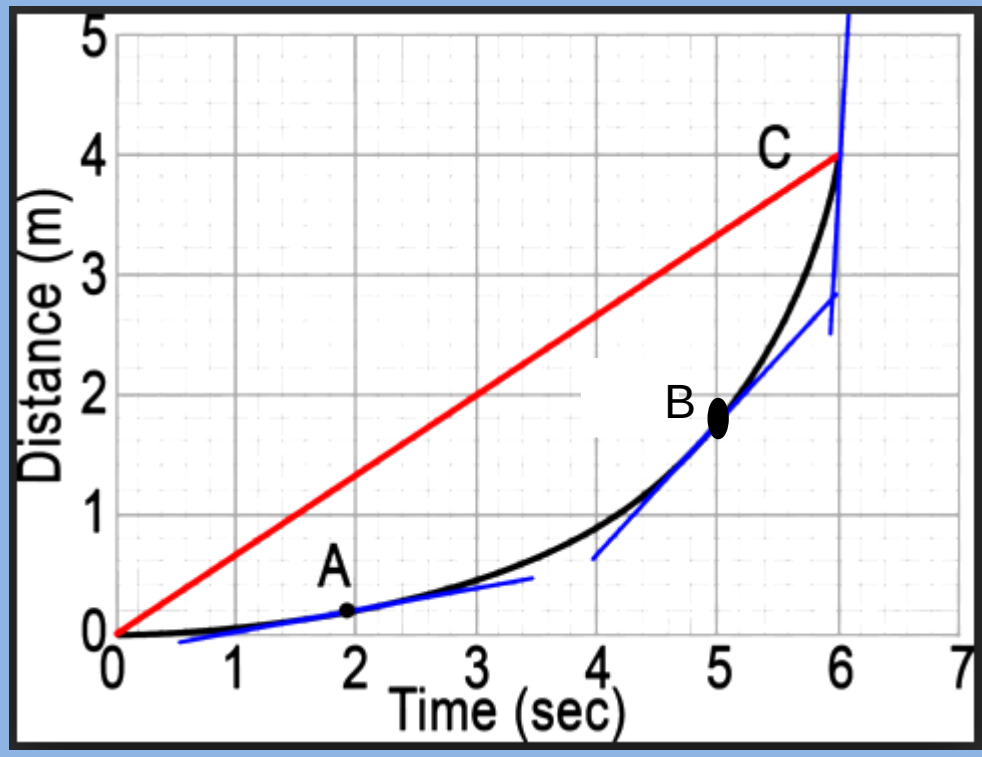
Types of Speed

INSTANTANEOUS speed

– speed at a given moment of time

A. 0.2 m / 1.9 s = 0.1 m/s

B. 1.8 m / 5 s = 0.36 m/s



CONSTANT speed

– speed does not change over time

– not shown on this graph

– Using cruise control

Types of Speed

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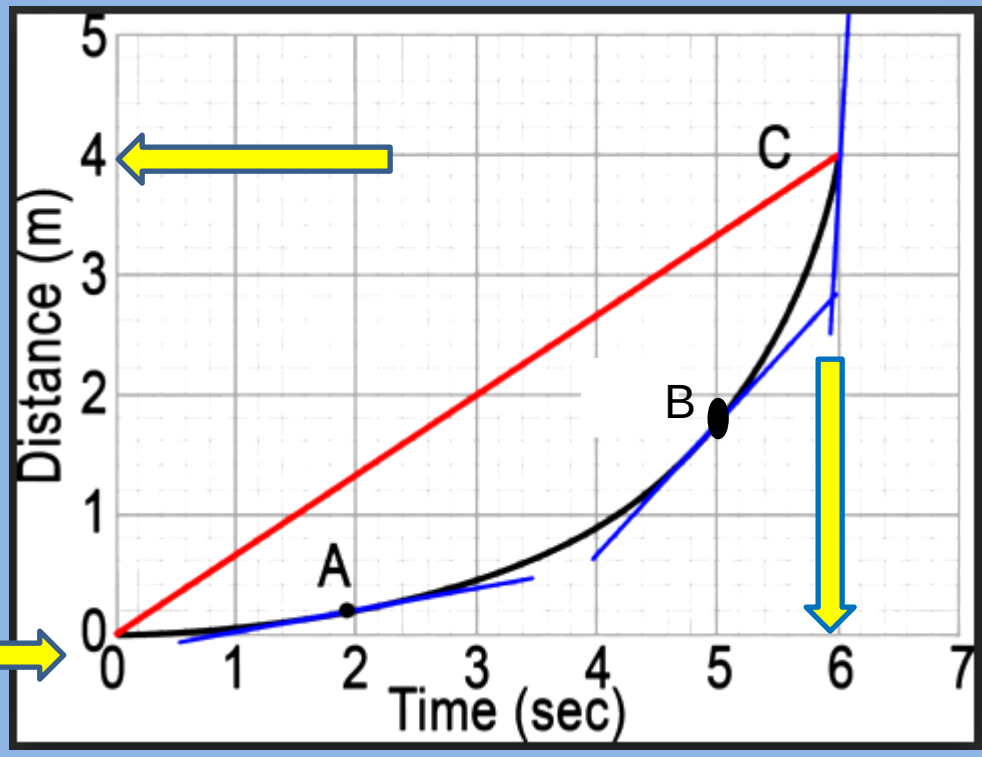


AVERAGE speed

→ total distance / total time

(4 m – 0 m) / (6 s – 0 s) = 0.67 m/s

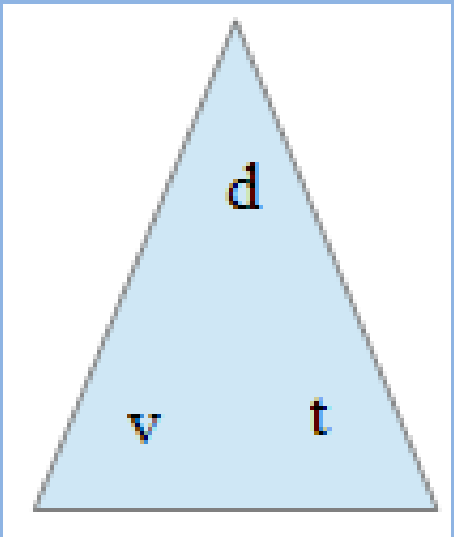
Speed Versus Velocity

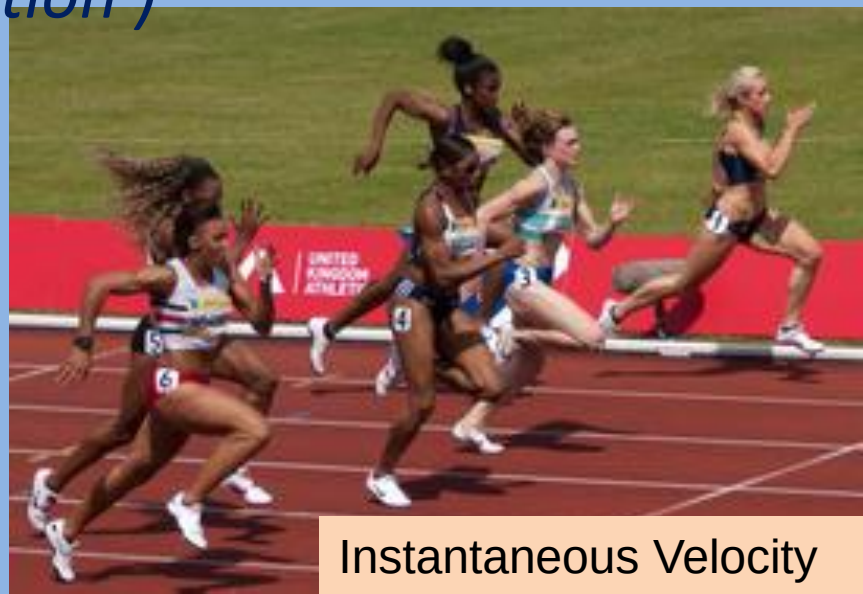
Speed **is a "scalar" quantity** described by a magnitude (or numerical value) alone.

Velocity **is a "vector" quantity** described by both a magnitude and a direction.

Velocity = displacement / time

(*velocity includes speed and direction)*





Instantaneous Velocity

Calculating Speed

QUICK CHECK

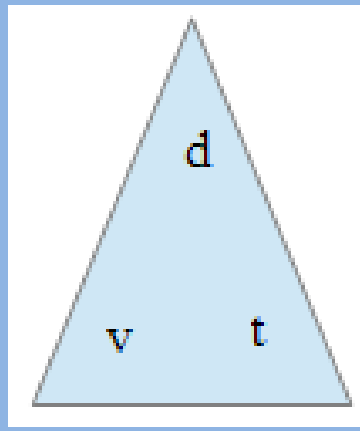
What is the average speed of a person who runs a distance of 15 km in a time interval of 60 minutes?

A

G

E

S



Calculating Speed

QUICK CHECK

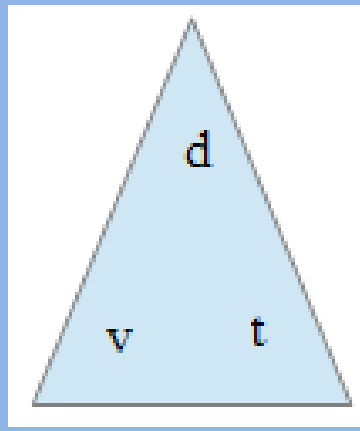
What is the average speed of a person who runs a distance of 15 km in a time interval of 60 minutes?

A Average speed

G d = 15 km; t = 60 min

E $v = d/t$

S $v = d/t = 15 \text{ km} / 60 \text{ min} = \underline{0.25 \text{ km/min}}$ or $\underline{2.5 \times 10^{-1} \text{ km/min}}$



Calculating Speed

QUICK CHECK

How far does a biker travel if she moves at an average speed of 12 km per hour for 3.5 hours?

A

G

E

S

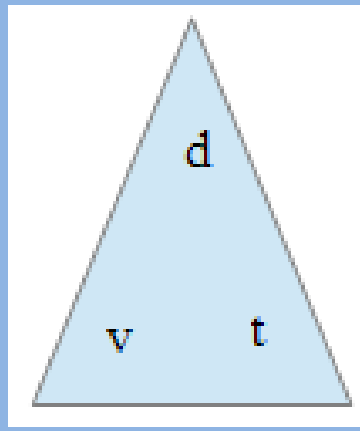
How long does it take a biker to travel 75 km at a speed of 30 km per hour?

A

G

E

S



Calculating Speed

QUICK CHECK

How far does a biker travel if she moves at an average speed of 12 km per hour for 3.5 hours?

A distance (how far)

G v = 12 km/hr; t = 3.5 hr

E $d = v\,t$

S $d = v\,t = 12\ km/hr \times 3.5\ hr = \underline{42\ km}$ or $\underline{4.2 \times 10^1\ km}$

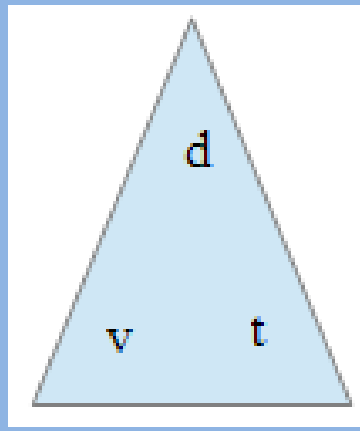
How long does it take a biker to travel 75 km at a speed of 30 km per hour?

A time (how long)

G d = 75 km; v = 30 km/hr

E $t = d/v$

S $t = d/v = 75\ km / 30\ km/hr = \underline{2.5\ hours}$



A woman jogs 10 kilometers in one hour, stops at a restaurant for one hour, and then walks 10 kilometers in two hours. What is her average speed for the outing?

A

G

E

S

A kayak is moving across a stream that is flowing downstream at a velocity of 4 km/h. The kayak's velocity is 3 km/h. What is the magnitude of the kayak's velocity relative to the river bank?

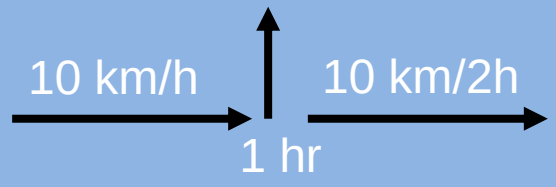
A

G

E

S

A woman jogs 10 kilometers in one hour, stops at a restaurant for one hour, and then walks 10 kilometers in two hours. What is her average speed for the outing?



A **average speed**

G **10 km in 1 hr; 0 km in 1 hr; 10 km in 2 hours**

E **avg v = total d / total t**

S **avg v = (10 km + 0 km + 10 km) / (1 hr + 1 hr + 2 hrs) =**

avg v = 20 km / 4 hr = 5 km/hr

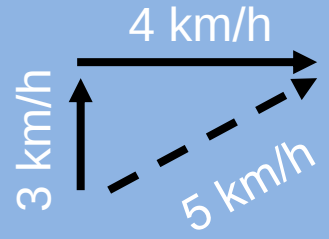
A kayak is moving across a stream that is flowing downstream at a velocity of 4 km/h. The kayak's velocity is 3 km/h. What is the magnitude of the kayak's velocity relative to the river bank?

A **velocity** **(3-4-5 triangle)**

G **stream 4 km/hr downstream; kayak 3 km/hr**

E $v^2 = v^2_{stream} + v^2_{kayak}$

S $v = \sqrt{(v^2_{stream} + v^2_{kayak})} = 5$ km/hr



Calculating Relative Velocity

A car moves 65 km due east, then 45 km due west. What is its total displacement?

An airplane flies at 200 km/h with respect to the air. What is the velocity of the plane relative to the ground if it flies with a 50 km/h tailwind? What if it flies into a 50 km/h headwind?

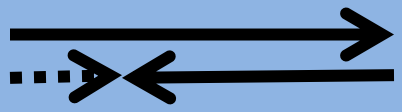
Calculating Relative Velocity

QUICK CHECK

A car moves 65 km due east, then 45 km due west. What is its total displacement?

Displacement is a vector quantity that includes direction

65 km - 45 km = <u>20 km due east</u>



An airplane flies at 200 km/h with respect to the air. What is the velocity of the plane relative to the ground if it flies with a 50 km/h tailwind? What if it flies into a 50 km/h headwind?

"Tailwind" means in the SAME direction as the airplane

200 km/h + 50 km/h = <u>250 km/h</u>

"Headwind" means in the OPPOSITE direction as the airplane

200 km/h - 50 km/h = <u>150 km/h</u>

Calculating Relative Velocity

The moving sidewalk at an airport has a speed of 0.9 m/s toward the departure gate. A man is walking toward the departure gate on the moving sidewalk at a speed of 1.0 m/s relative to the sidewalk. What is the velocity of the man relative to a woman standing off the moving sidewalk?

Calculating Relative Velocity

QUICK CHECK

The moving sidewalk at an airport has a speed of 0.9 m/s toward the departure gate. A man is walking toward the departure gate on the moving sidewalk at a speed of 1.0 m/s relative to the sidewalk. What is the velocity of the man relative to a woman standing off the moving sidewalk?

Since the man is ON the moving sidewalk, and the woman is standing OFF the moving sidewalk, add the velocities:

0.9 m/s + 1.0 m/s = 1.9 m/s toward the departure gate

Calculating Relative Velocity

On a similar moving sidewalk moving (0.9 m/s) in the **opposite direction**, a child walks toward the **terminal** at a speed of 0.4 m/s relative to the sidewalk. What is the velocity of the man relative to the child?

Calculating Relative Velocity

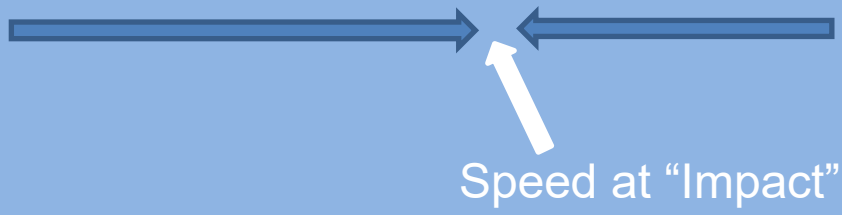
QUICK CHECK

On a similar moving sidewalk moving (0.9 m/s) in the **opposite direction**, a child walks toward the **terminal** at a speed of 0.4 m/s relative to the sidewalk. What is the velocity of the man relative to the child?

man → 0.9 m/s + 1.0 m/s = 1.9 m/s toward the departure gate

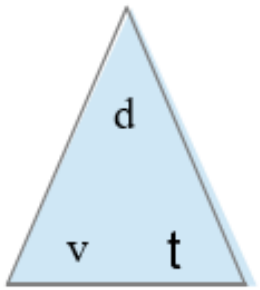
child → 0.9 m/s + 0.4 m/s = 1.3 m/s away from the departure gate = -1.3 m/s

1.9 m/s – (-1.3 m/s) = 3.2 m/s relative to each other



Physical Science Formula Sheet

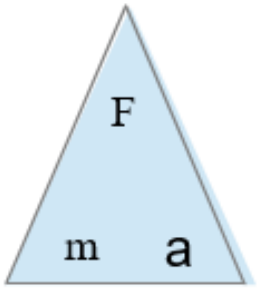
$s = d / t$ $\quad v = d / t$



$a = \Delta v / t$

$a = \dfrac{v_f - v_i}{t}$

$F = m\,a$



$d = \frac{1}{2}\,at^2$

$v_{instantaneous} = g \cdot t$

Total Energy = PE + KE

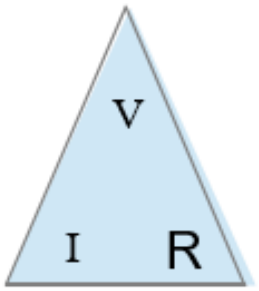
$PE = mgh$

$KE = \frac{1}{2}\,mv^2$

$p = m \cdot v$

$P = W / t$

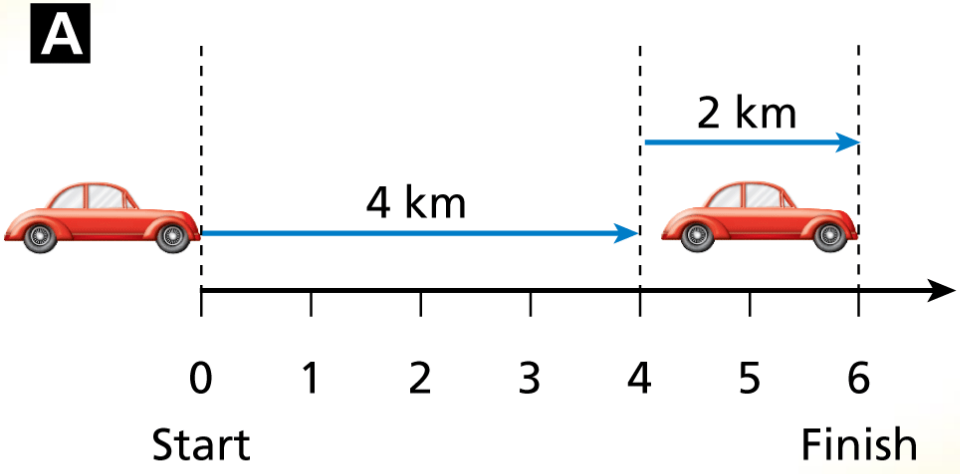
$V = I \cdot R$



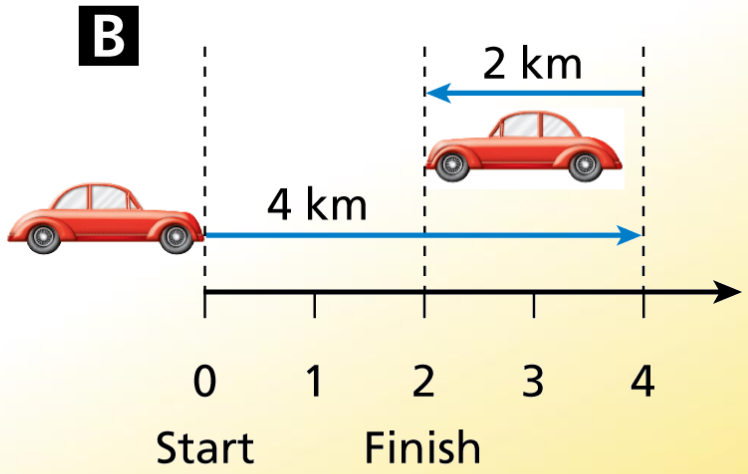
Combining Displacements

A. Add the magnitudes of two displacement vectors that have the same direction.

B. Two displacement vectors with opposite directions are subtracted from each other.



4 km + 2 km = 6 km



4 km – 2 km = 2 km

Combining Displacements

Displacement That Isn't Along a Straight Path

When two or more displacement vectors have different directions, they may be combined by graphing.

Combining Displacements

Measuring the resultant vector (the diagonal red line) shows that the displacement from the boy's home to his school is two blocks less than the distance he actually traveled.

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Combining Displacements

The boy walked a total distance of 7 blocks. This is the sum of the magnitudes of each vector along the path.

The vector in red is called the **resultant vector,** which is the vector sum of two or more vectors.

The resultant vector points directly from the starting point to the ending point.

Assessment Questions

1. A car is driving down the highway. From which frame of reference does it appear to not be moving?
   a. standing at the side of the road
   b. a car driving at the same speed but going the opposite direction
   c. sitting inside the car
   d. an airplane flying overhead

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   ANS: C

Assessment Questions

2. The SI unit of distance that would be most appropriate for measuring the distance between two cities is the
   a. meter.
   b. centimeter.
   c. kilometer.
   d. mile.

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   ANS: C

Assessment Questions

3. If you walk across town, taking many turns, your displacement is the
   a. total distance that you traveled.
   b. distance and direction of a straight line from your starting point to your ending point.
   c. distance in a straight line from your starting point to your ending point.
   d. direction from your starting point to your ending point.

Assessment Questions

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   a. total distance that you traveled.
   b. distance and direction of a straight line from your starting point to your ending point.
   c. distance in a straight line from your starting point to your ending point.
   d. direction from your starting point to your ending point.

   ANS: B

Assessment Questions

4. You travel 30 miles west of your home and then turn around and start going back home. After traveling 10 miles east, what is your displacement from your home?
   a. 20 km
   b. 20 km west
   c. 40 km
   d. 40 km west

Assessment Questions

4. You travel 30 miles west of your home and then turn around and start going back home. After traveling 10 miles east, what is your displacement from your home?

   a. 20 km
   b. 20 km west
   c. 40 km
   d. 40 km west

   ANS: B

Combining Velocities

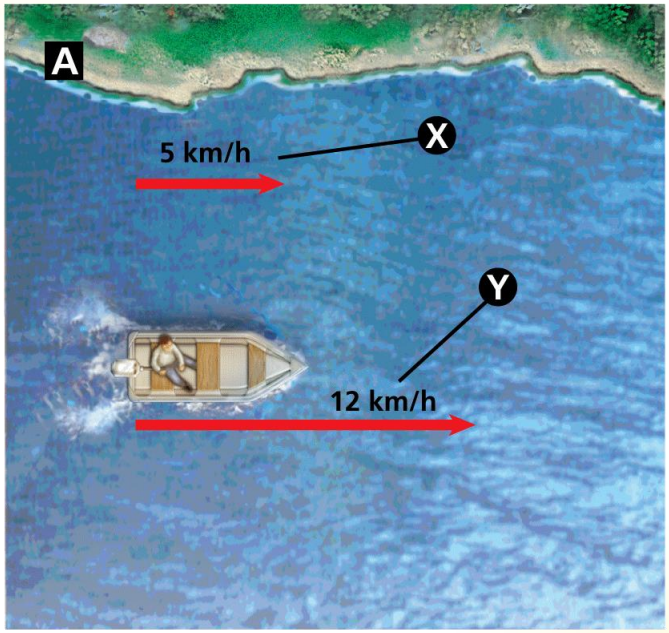
Sometimes the motion of an object involves more than one velocity.

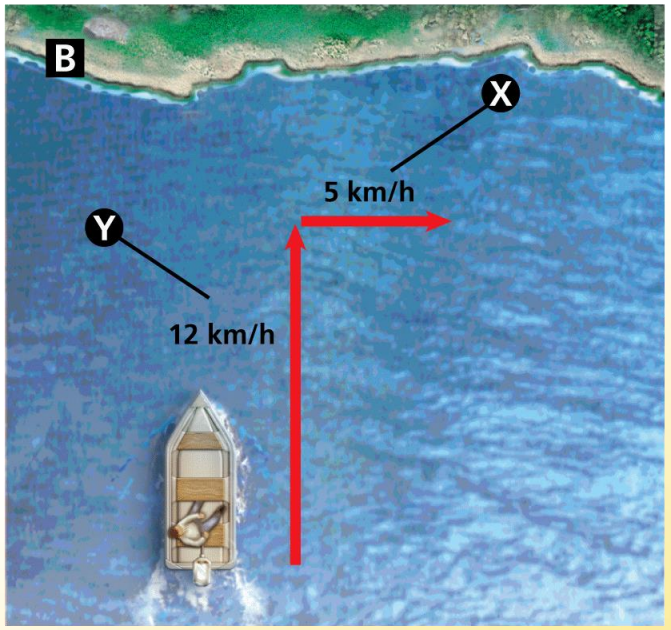
If a boat is moving on a flowing river, the velocity of the river relative to the riverbank and the velocity of the boat relative to the river combine.

They yield the velocity of the boat relative to the riverbank.

Combining Velocities

The velocity of the boat relative to the riverbank is a combination of the relative velocities of the boat and the river.





Combining Velocities

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