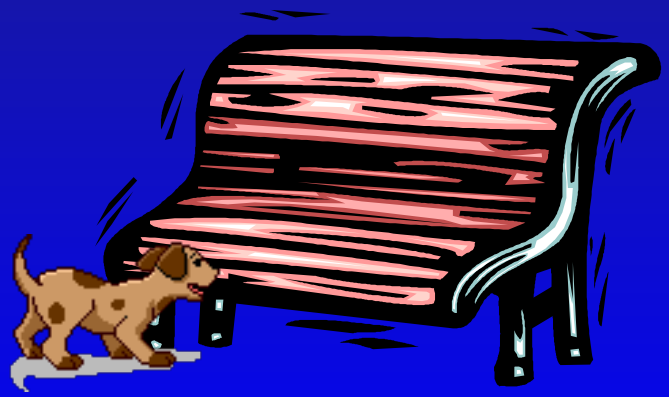
Motion & Newton's Laws

State Objectives 2.c. & 2.f.

What is MOTION?
All matter is in constant motion

- Motion is any change in position
- Relative Motion is used to recognize a change in position by using a point of reference
  - An object changes positions if it moves relative to a reference point

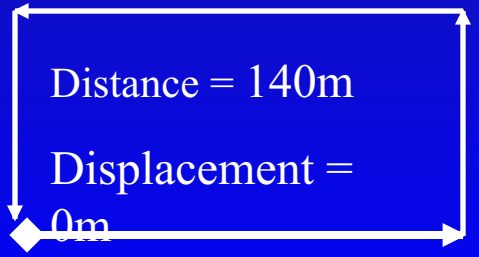


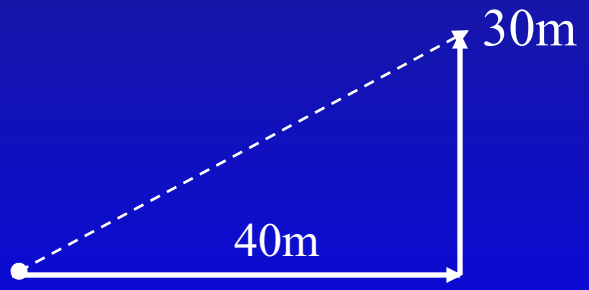
Measuring Motion

- Distance is the total length of the route an object travels when it moves
- Displacement includes distance from the starting point to the stopping point and the **direction** traveled
- Ex.

Distance = 40m

Displacement = 40m east





Distance = 70m

Displacement = 50m northeast

Speed

- Speed is the distance traveled divided by the time taken to travel the distance
- Formula: Speed = distance ÷ time (S=D/T)
- SI Unit: meters per second (m/s)
- Ex. In the 100m dash the fastest runner finished in 10s. S= 100m/10s= 10m/s
- 3 Types of Speed
  - Average speed is found by dividing the total distance by the total time taken to reach that distance
    - Speeds can vary from instant to instant
    - Ex. Walking in a crowded hallway
  - Instantaneous Speed is the speed of an object at a particular moment
  - Constant Speed is when an object is moving at a steady rate throughout the entire distance.

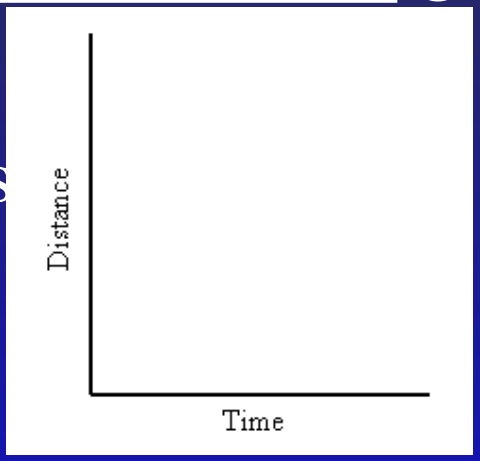
Practice Problem

- Calculate the Average Speed. Round to the nearest 0.1m/s
  - A swimmer swam 100m in 56s.

- Answer: S=100m/56s
  - 1.8m/s

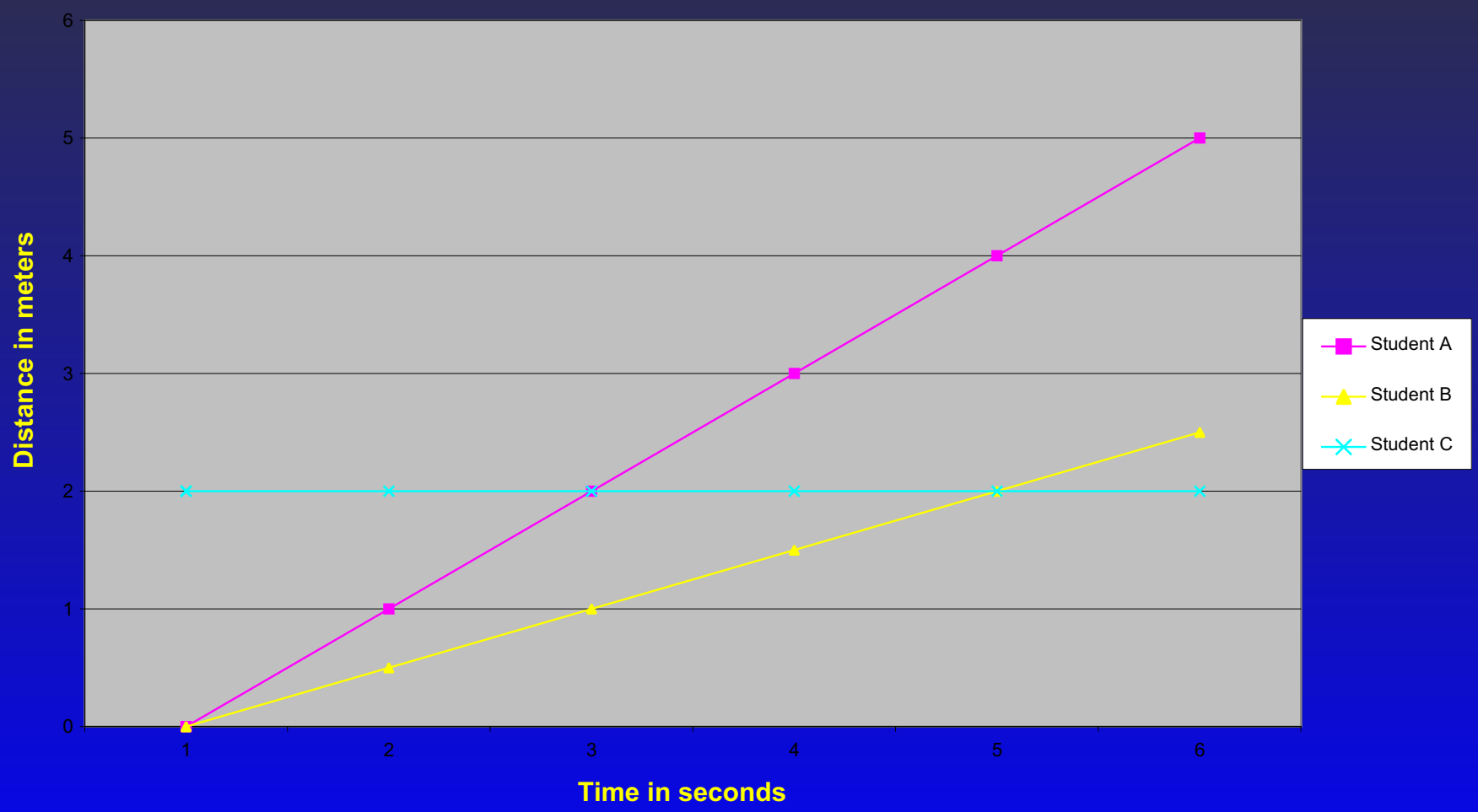
Graphing Motion

- Motion can be graphed on a distance-time graph
  - Time on the horizontal (X) axis
  - Distance on the vertical (Y) axis

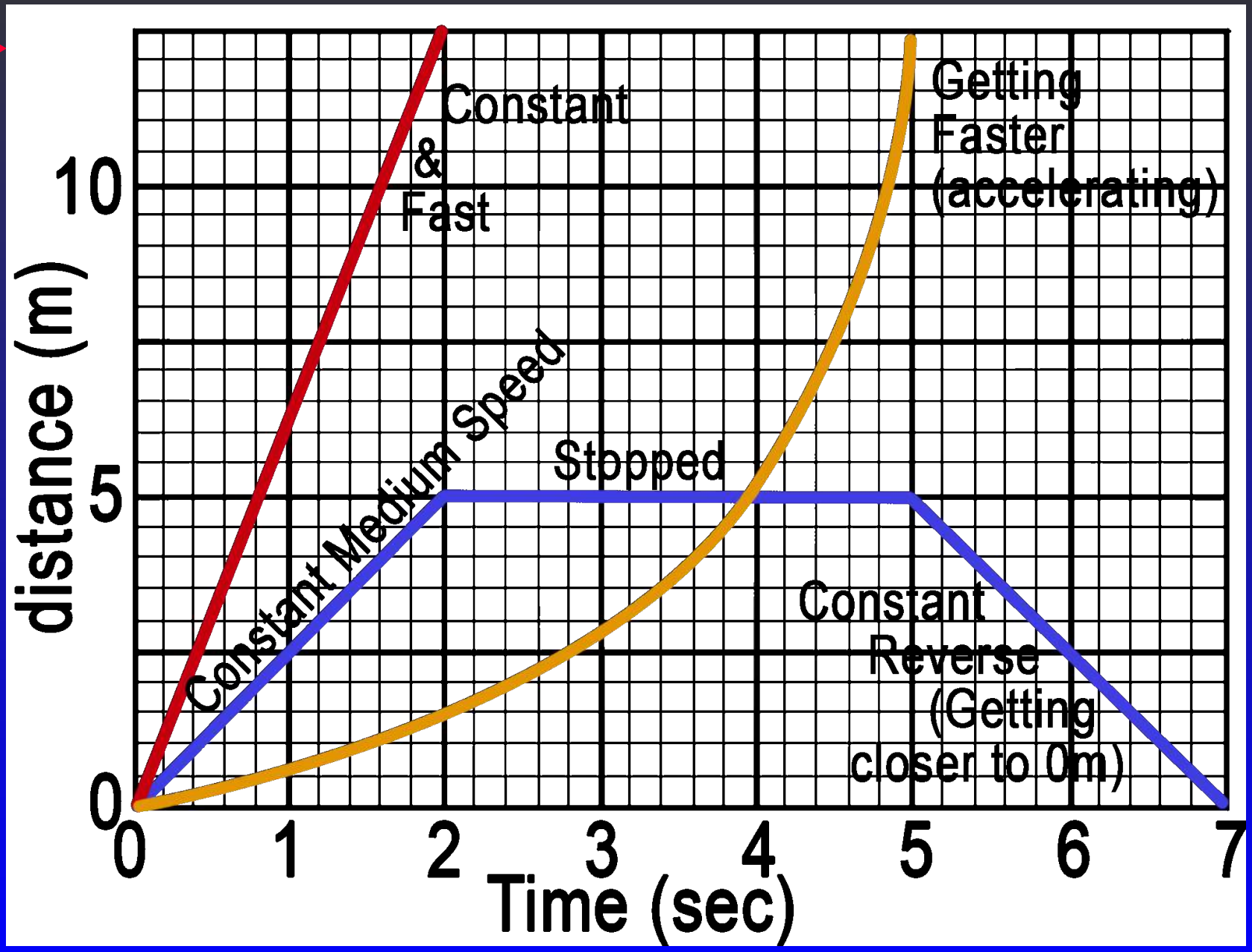


  - The steeper the line on a distance-time graph, the greater the speed
  - A horizontal line means no change in position, which makes the speed "zero" at anytime on the graph

Example Graph



- Which student is moving fastest?
- Which student has no motion?


Constant
&
Fast
Getting
Faster
(accelerating)
Constant Medium Speed
Stopped
Constant
Reverse
(Getting
closer to 0m)
distance (m)
10
5
0
0
1
2
3
4
5
6
7
Time (sec)

Velocity

- Velocity is the speed of an object and the direction of its motion.
- Unit is same as speed, but includes direction
  - 10km/h east

Example: A hiker needs to know how far away the camp is & in what direction to determine the necessary velocity to get back to camp before nightfall

Acceleration

- Acceleration occurs when an object changes its motion (velocity changes)
  - Speed up - 50mi/h to 60mi/h (positive)
  - Slow down – 45mi/h to 40mi/h (negative)
    - Acceleration is in the opposite direction of the motion
  - Change in direction – north to east
    - Basketball thrown from the free-throw line

Can you think of examples of situations that have positive or negative acceleration?

Calculating Acceleration

- If an object's motion is in a straight line the acceleration can be calculated using this formula:

$$\text{(a)Acceleration} = \frac{\text{final speed}(s_f) - \text{initial speed}(s_i)}{\text{Time}(t)}$$

- Unit for acceleration is m/s^2
- Ex. Calculate the acceleration of a bus whose speed changes from 6m/s to 12m/s over a period of 3s.
  - Initial speed: 6m/s
  - Final speed: 12m/s
  - Time: 3s

$$A = \frac{12m/s - 6m/s}{3s}$$

$$A = 2m/s^2$$

Practice Problems

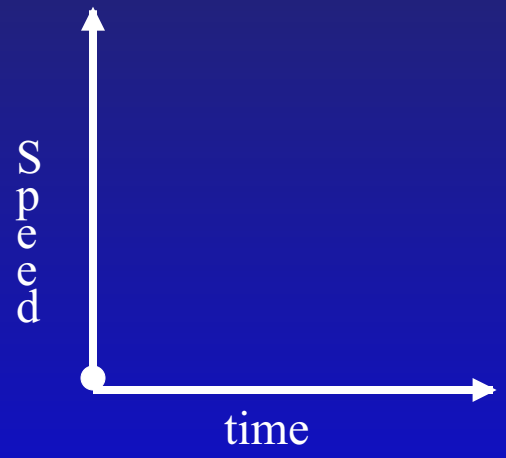
1. A train's velocity increases from 7m/s to 18m/s over a period of 120s.

2. Jack was riding a bike in a straight line and sped up from 4m/s to 6m/s in 5s.

3. Sarah slowed down from 4m/s to 2m/s in 5s as she walked her last lap on the track.

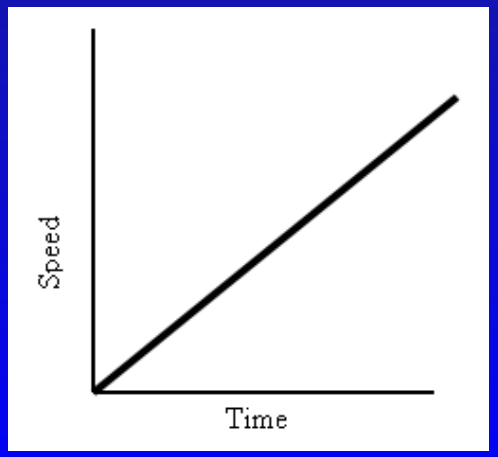
Graphing Acceleration

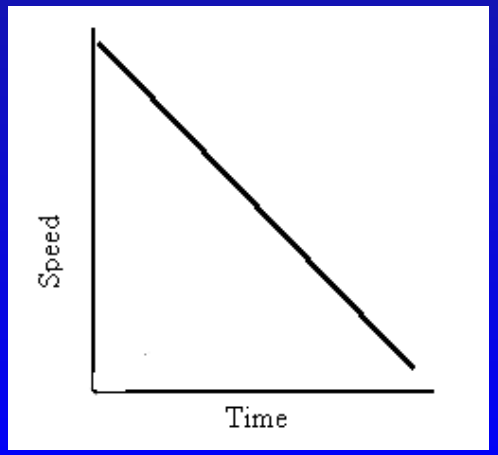
- Accelerated motion can be graphed by putting speed on the vertical axis and time on the horizontal axis

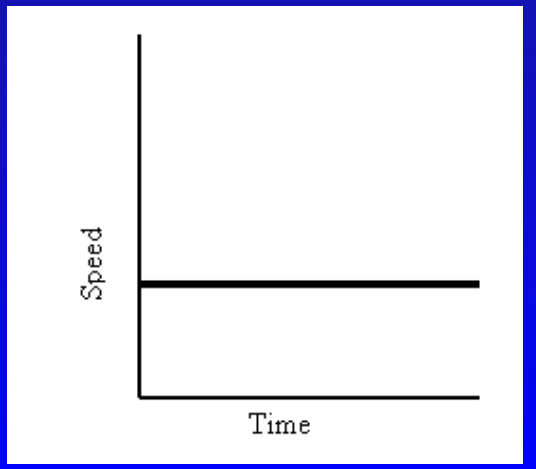


Graphing Acceleration

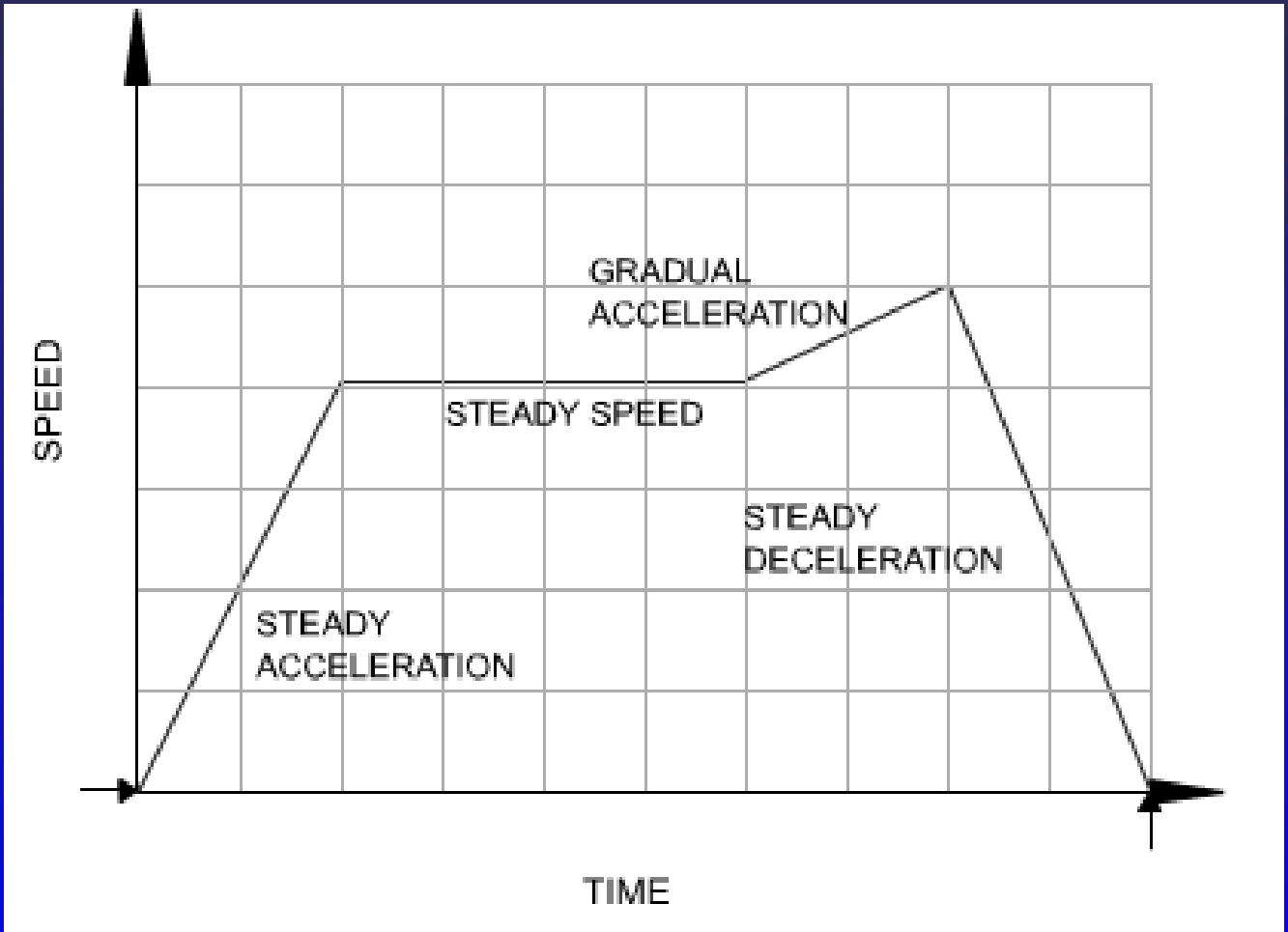
- An object that is speeding up will have a line that will slope upwards (positive line)
- An object that is slowing down will have a line that will slope downward (negative line)
- A horizontal line would indicate an acceleration of zero, or a constant speed





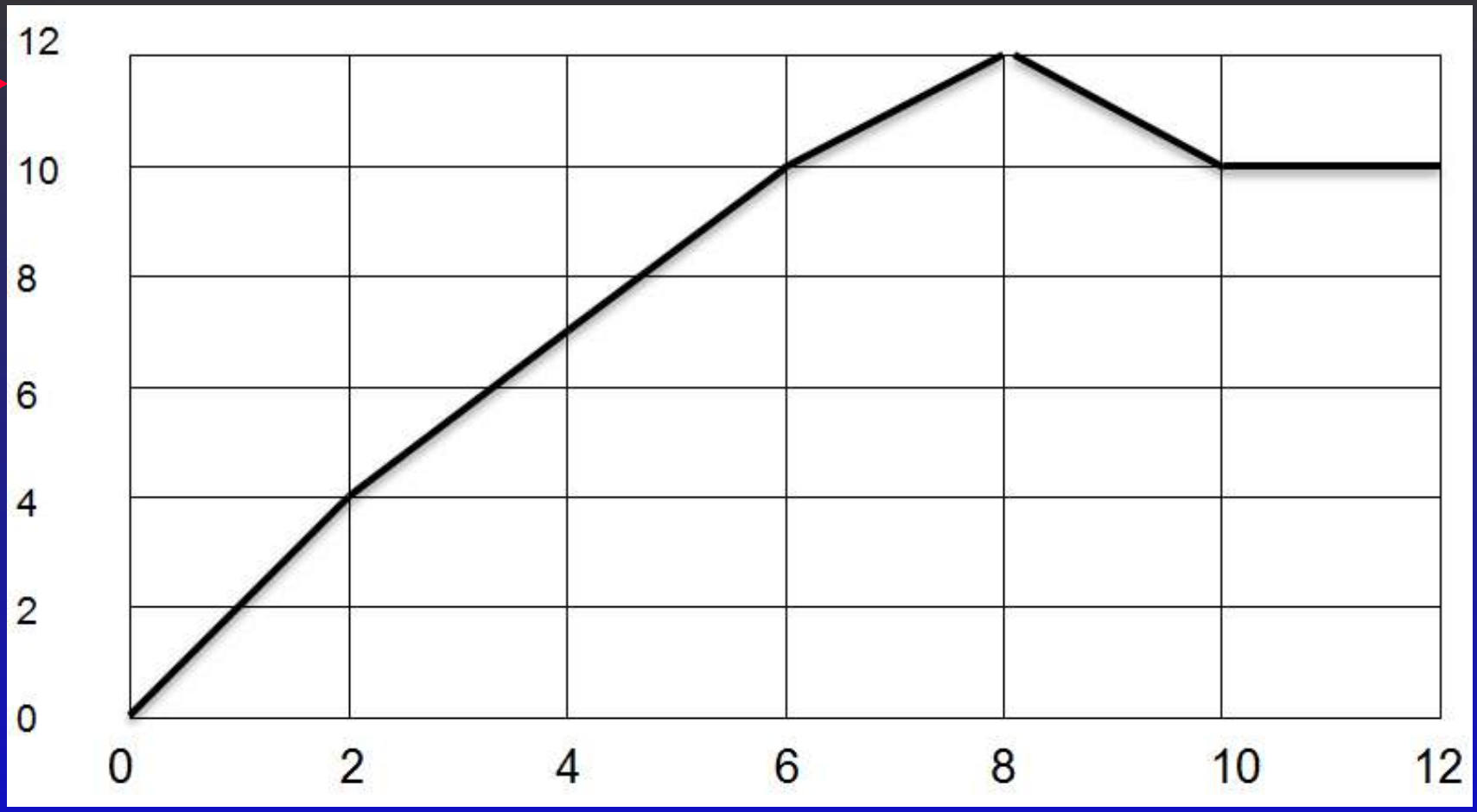


Example Graph



Practice Graphing

- A sprinter had the following speeds at different times during a race: 0m/s at 0s, 4m/s at 2s, 7m/s at 4s, 10m/s at 6s, 12m/s at 8s, 10m/s at 10s and 10m/s at 12s. Plot this data on a speed-time graph



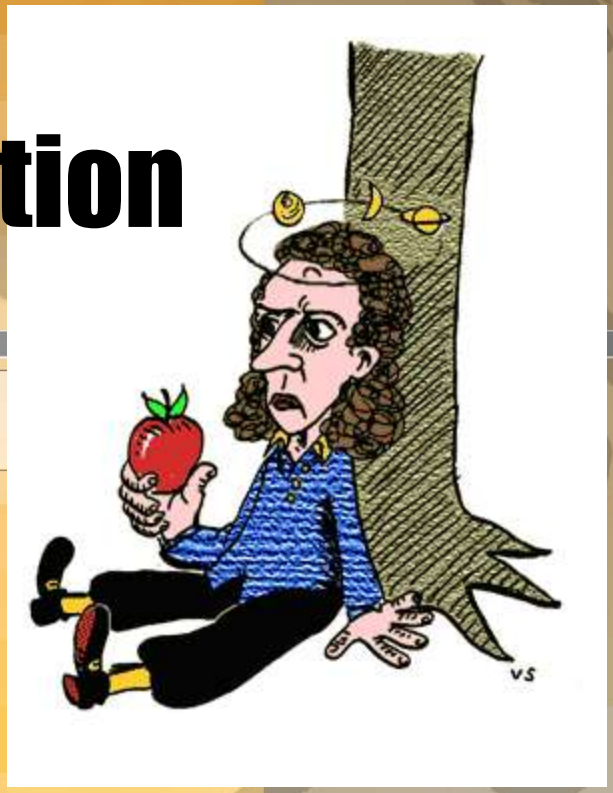
1. During what interval is the acceleration positive?
2. Negative?
3. Is the acceleration ever zero? Explain.

Simulation Review

- http://phet.colorado.edu/en/simulation/moving-man

Newton's 3 Laws of Motion

State Objective 2.f.



What is a Force?

- Force is defined as a push or a pull
  - Ex. Pushing a grocery cart or pulling a wagon

- Net force is the combination of all forces acting on an object at the same time.
- Ex: Identify all the forces acting on a paper clip, sitting on a table, near a magnet.

Balanced verses Unbalanced

- **Balanced forces occur when two or more forces exerted on an object cancel each other out causing no change in motion (no acceleration)**
  - Ex. Lean back to back with a partner with no motion or hold a book in your hand very still

- **Unbalanced forces occur when the combined forces acting on an object do not cancel each other out causing a change in motion (acceleration)**
  - **Ex. Push a chair with wheels or when someone wins tug-a-war**

Decide if the situation is Balanced or Unbalanced

1. Push a box till it moves U
2. Pedal a bike at a constant speed B
3. Apply brakes to a bike in order to pop a wheelie U
4. Push a car that never moves B
5. Two people push a box in opposite directions causing the box to go nowhere B
6. Two people push a box in opposite directions causing the box to slide slightly to the right. U

Newton's First Law of Motion

- An object at rest will remain at rest until an unbalanced force is applied.
  - Ex: A football player kicking a ball
- An object in motion will remain in motion until an unbalanced force is applied.
  - Ex: A rocket in space will move in a straight line.
- Known as the "law of inertia"
  - Inertia is the tendency of an object to resist change in its motion
    - Ex. Coach Brown slamming on the brakes and your body goes forward.

Friction

- Friction is a force that resists sliding between two touching surfaces or through air or water.
- Example: A baseball player sliding into second base.
  - Friction slows down an object's motion.
  - Friction produces heat and wears on objects.
  - Friction always acts against the direction of motion.
  - What are some examples of friction?

Gravity

- Gravity is the force of attraction between two objects.
- The strength of gravity depends on an object's mass and distance.
- For example, the moon's gravity is 1/6 of the Earth's gravity because it is much smaller.
- Where would gravity be less, at sea level or on top of a mountain?

Newton's 2nd Law

- Newton's second law of motion states that an object acted upon by a force will accelerate in the direction of the force.
  - Force equals mass times acceleration.
    - Ex. A baseball or a bowling ball: Which one requires more force to throw the same distance?
    - Formula: $a = f \div m$ or $f = m \times a$
    - Forces are measured in Newtons (N)
      - $1N = 1kg \times 1m/s^2$

Practice Newton's 2nd law

- Suppose you pull a 10kg sled with a force of 5N. What is the acceleration of the sled?

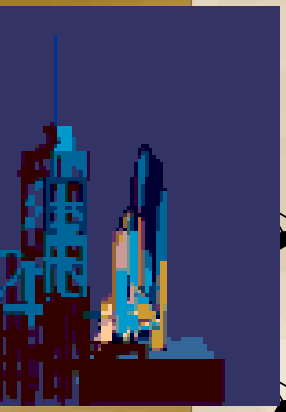
  $A = 5N \div 10kg = \underline{0.5m/s^2}$

- You throw a baseball with a mass of .5 kg so it has an acceleration of $40m/s^2$. How much force did you exert on the baseball?

  Answer: <u>20 N</u>

- Explain the connection between motion, 1st law, & 2nd law.

Newton's 3rd Law



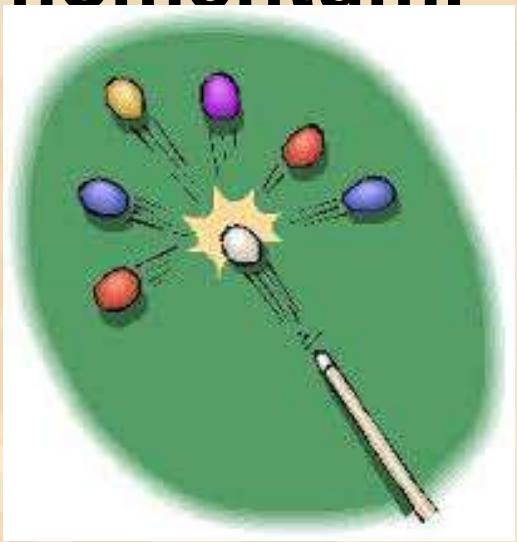
- Newton's third law of motion states that for every action, there is an equal but opposite reaction.
- Forces always act in pairs.
  - Bounce a ball on the ground or playing pool
- Action-reaction forces are always the same size but are in opposite directions and act on different objects.
  - When the mass of one object is considerably larger than the mass of another object, the action-reaction force is not noticeable.
    - When you push a wall or walk on the earth.

Action/Reaction Forces

- **When one object exerts a force on another object the 2nd object exerts the same size force on the 1st object**
- **Forces act on different objects, so they do not cancel each other out**
  - **http://www.school-for-champions.com/science/newtons_cradle.htm**
  - https://youtu.be/BiLq5Gnpo8Q (myth buster's clip)

Collision

- **Two or more objects that come in contact with each other in which each exerts a force upon the other, causing the exchange of energy or momentum.**



Action/ Reaction Examples
Underline the object

Action	Reaction
•Wings push air down & back	•Air pushes wings up and forward
•Hands push water back	•Water pushes swimmer forward
•Foot pushes down and back on earth	•Earth pushes foot up &forward
•Rocket engine pushed gas molecules downward	•Gas molecules push rocket up

Why does the reaction not always appear to be the same?

•The greater the mass the greater the inertia

Nasa Video for Review

- https://youtu.be/KvPF0cQUW7s

Which law?

1. Using an oar to move a canoe

3rd

2. Pushing a swing with more force to move your big brother than you did with your little sister

2nd

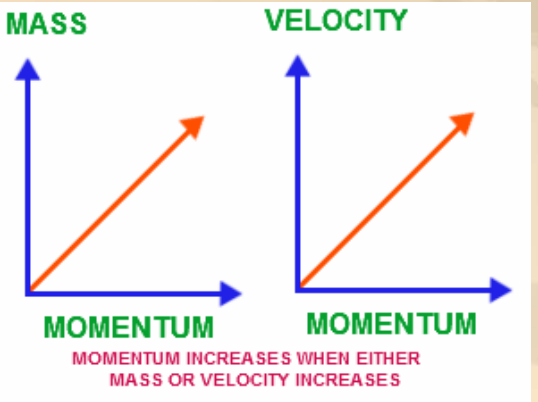
3. A rock is sitting on a hill until you push it causing it to roll

1st

Quiz

Momentum

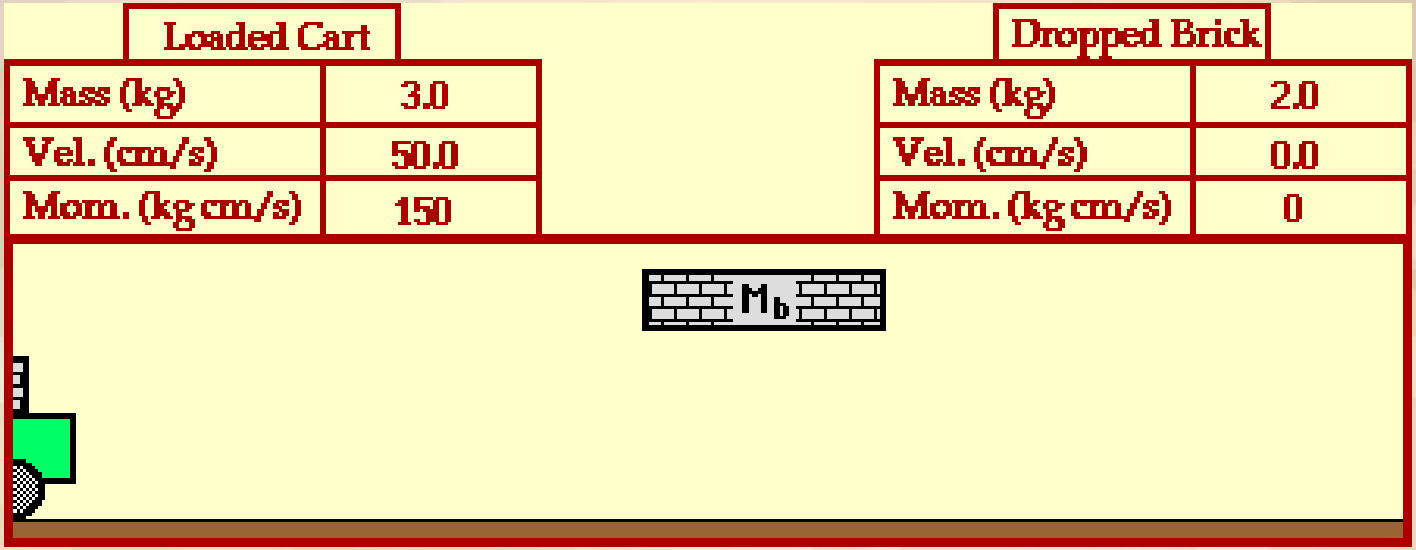
- Momentum is a measure of how hard it is to stop an object.
- Momentum increases if either mass or velocity increases.



- Formula for momentum
  - P=mv. P is symbol for momentum. Mass is in kg. Velocity is in m/s.
  - The unit for momentum is kg*m/s.

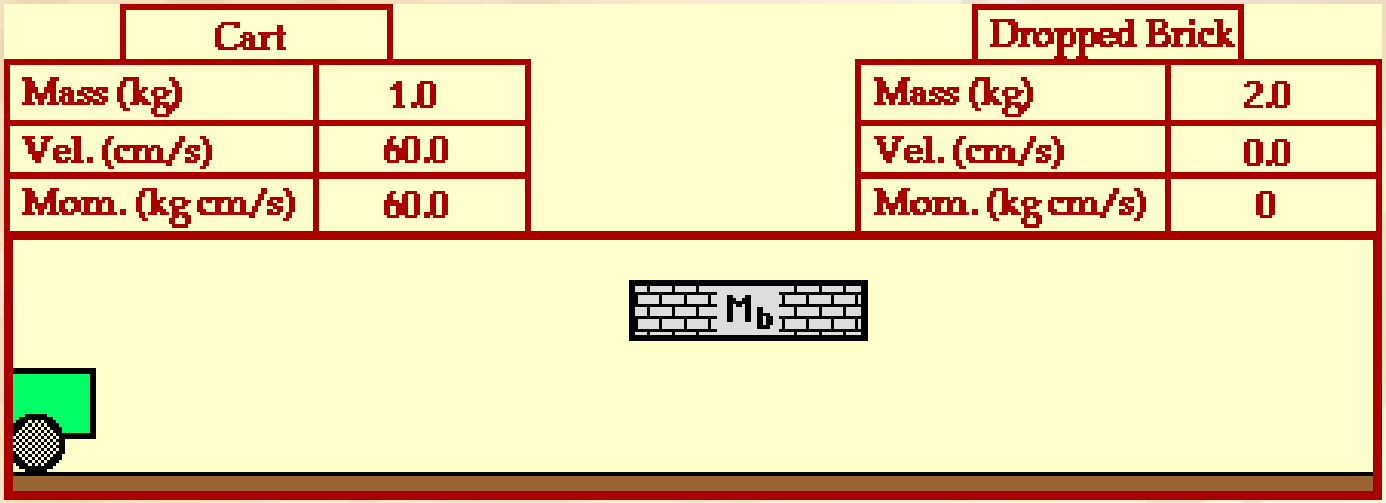
Loaded Cart	
Mass (kg)	3.0
Vel. (cm/s)	50.0
Mom. (kg cm/s)	150

Dropped Brick	
Mass (kg)	2.0
Vel. (cm/s)	0.0
Mom. (kg cm/s)	0



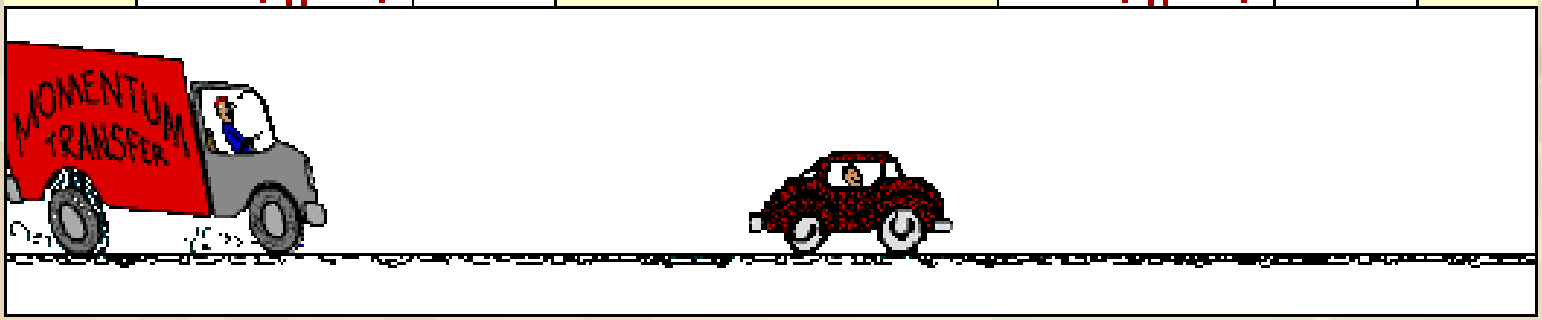
Cart	
Mass (kg)	1.0
Vel. (cm/s)	60.0
Mom. (kg cm/s)	60.0

Dropped Brick	
Mass (kg)	2.0
Vel. (cm/s)	0.0
Mom. (kg cm/s)	0



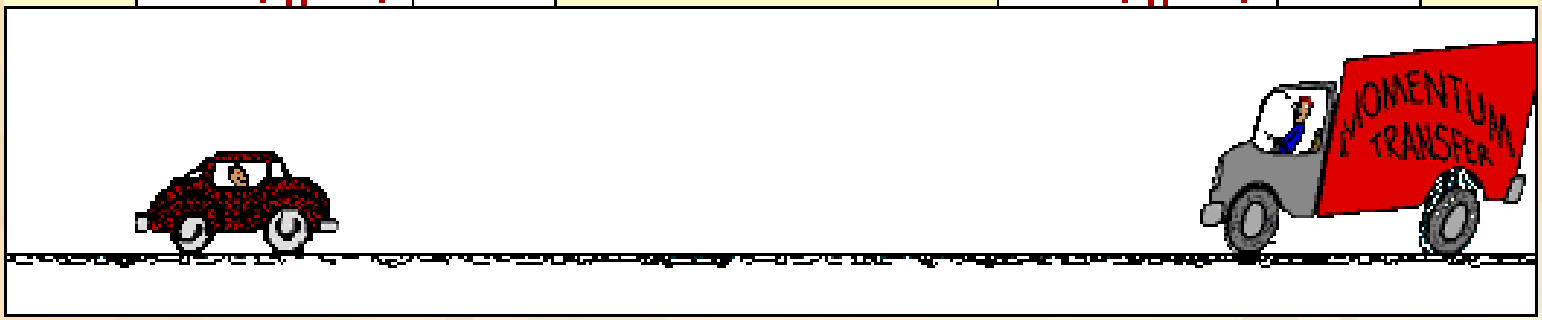
Truck	
mass (kg)	3000
vel. (m/s)	20.0
mom. (kg m/s)	60 000

Car	
mass (kg)	1000
vel. (m/s)	0.0
mom. (kg m/s)	0



Car	
mass (kg)	1000
vel. (m/s)	20.0
mom. (kg m/s)	20 000

Truck	
mass (kg)	3000
vel. (m/s)	-20.0
mom. (kg m/s)	-60 000



Momentum

- **Which would be harder to stop if moving at the same velocity, a 2,000 kg car or a 4,000 kg truck?**

Conservation of Momentum

- The law of conservation of momentum states that the total momentum of two objects that collide is the same before and after a collision.

Truck	
mass (kg)	3000
vel. (m/s)	20.0
mom. (kg m/s)	60 000

Car	
mass (kg)	1000
vel. (m/s)	0.0
mom. (kg m/s)	0