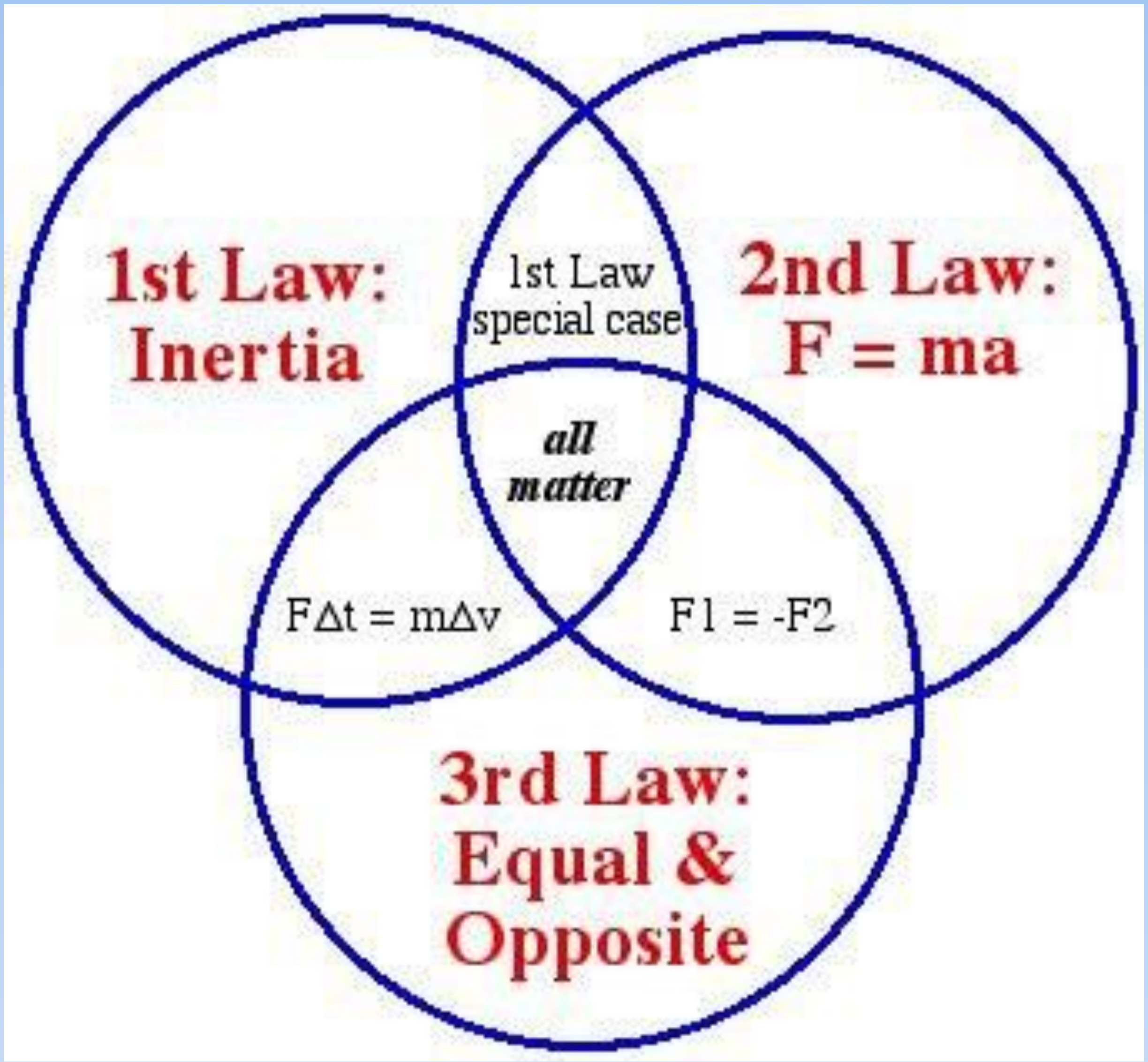
Newton's Laws of Motion



Which Lands First?

WARM-UP

THINK ABOUT IT

Galileo drops two objects from the same height off the Tower of Pisa in Italy.

One object is like a bowling ball and the other like a tennis ball.

Assuming there is NO wind resistance, **PREDICT** which ball will hit the ground first.

Observing Motion?

Suppose you are standing in the aisle of a jumbo jet parked at its terminal. You jump straight up. Where will you land? That is an easy question to answer. You will land in the same place from which you jumped. **But now suppose the jet is moving at a speed of 600 km/hr. You jump straight up again. Where will you land?**

Go to Study Place and download "Newton's 1st Law Activity".

- **Perform procedures 1-6 and return back in 4 minutes.**
- **Do NOT spend time on the drawings. You can do that during the week if you want.**

Observing Motion?

WARM-UP

THINK ABOUT IT

Newton's 1st Law Activity Sketches

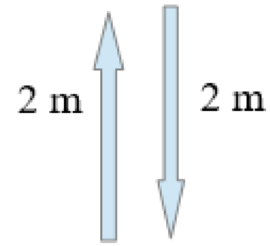
WARM-UP

Observing Motion?

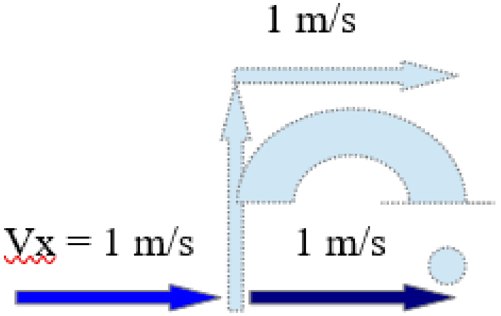
THINK ABOUT IT

Newton's 1st Law Activity Sketches

1. While standing still, throw a small solid ball straight up about 2 m high. Sketch.

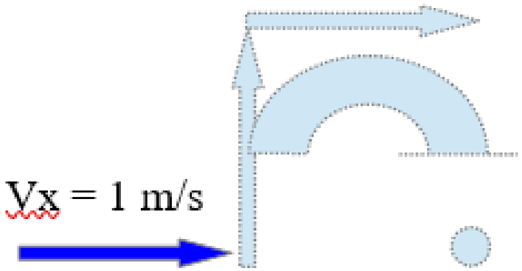


2. Now walk at a constant speed and throw the ball straight up. Where does the ball land? Sketch.



Vx for you and the ball is the same

3. Continue walking at a constant speed. This time, stop instantly just after you release the ball upward. Where does the ball land? Sketch.



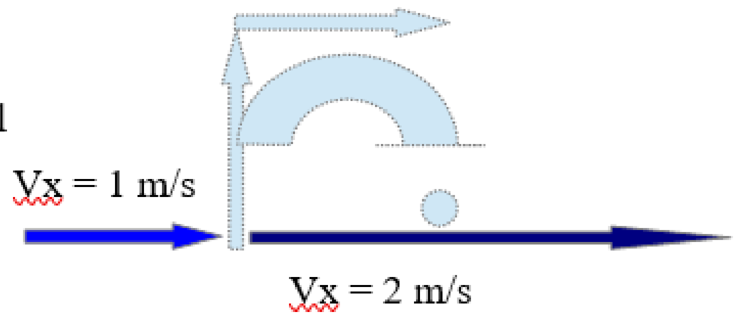
Observing Motion?

WARM-UP

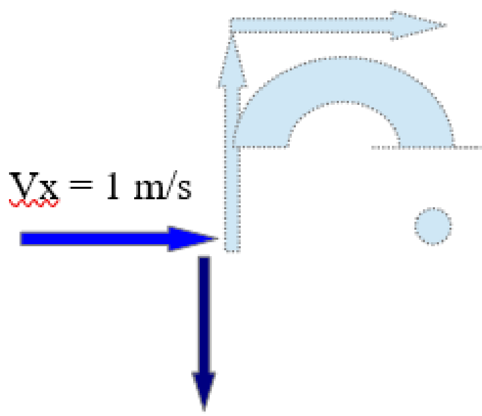
THINK ABOUT IT

Newton's 1st Law Activity Sketches

4. Continue walking at a constant speed. Just after you release the ball upward, break into a run. Where does the ball land? Sketch.



5. Continue walking at a constant speed. Just after you release the ball upward, make a sharp right turn. Where does the ball land? Sketch.



What is another name for "arrows that indicate direction" in Physics? **Vectors**
These have **magnitude** and **direction**.

Observing Motion?

WARM-UP

THINK ABOUT IT

1. While standing still, throw a small solid ball straight up about 2 m high. Does it land in your hand?

The ball lands back in your hand.

2. Now walk at a constant speed and throw the ball straight up. Where does the ball land?

The ball lands back in your hand.

3. Continue walking at a constant speed. This time, stop instantly just after you release the ball upward. Where does the ball land?

The ball continues to go forward and lands 1-2 meters in front of you.

4. Continue walking at a constant speed. Just after you release the ball upward, break into a run. Where does the ball land?

The ball continues to go forward, but since you accelerate, you go beyond where the ball lands … it lands behind you.

5. Continue walking at a constant speed. Just after you release the ball upward, make a sharp right turn. Where does the ball land?

The ball continues to go straight, while you turn the corner.

6. Where would you land on the jumbo jet that is moving at 600 km/hr?

You would land in the same spot that you jumped from because you are moving at the same speed as the jet. Your jump pattern would make a parabolic shape.

Observing Motion?

Newton's 1st Law Activity Demo

Projectile Motion

Showing the cart and ball BOTH moving with constant velocity … and showing the ball moving in a curved path.

http://somup.com/cFXh00n1kH (0:15)

http://somup.com/cFXh0bn1kE (0:27)

LESSON QUESTION

Focus Questions

1. Explain & recognize Newton's First Law of Motion, **Inertia**, as the tendency of matter to resist change in motion.
2. Understand and explain **friction** [recognizing four kinds of friction] as a force that opposes motion, producing negative acceleration or "deceleration".
3. Explain & calculate variables of Newton's Second Law of Motion, **f = ma**, describing how force, acceleration, and mass are related. Force equals mass times acceleration.
4. Explain & recognize Newton's Third Law of Motion which states that forces always occur in pairs. Every **action** has an equal and opposite **reaction**.
5. Recognize momentum (mv, angle) in the motion of objects.

LESSON QUESTION

OBJECTIVES

1. Students should be able to recognize, explain, and work with the Laws of Motion by their general name:

    a. First Law of Motion → inertia

    b. Second Law of Motion → f = ma

    c. Third Law of Motion → action/reaction

    d. Momentum → ρ = mv

2. Students should be able to state how forces affect motion (*forces cause motion*).

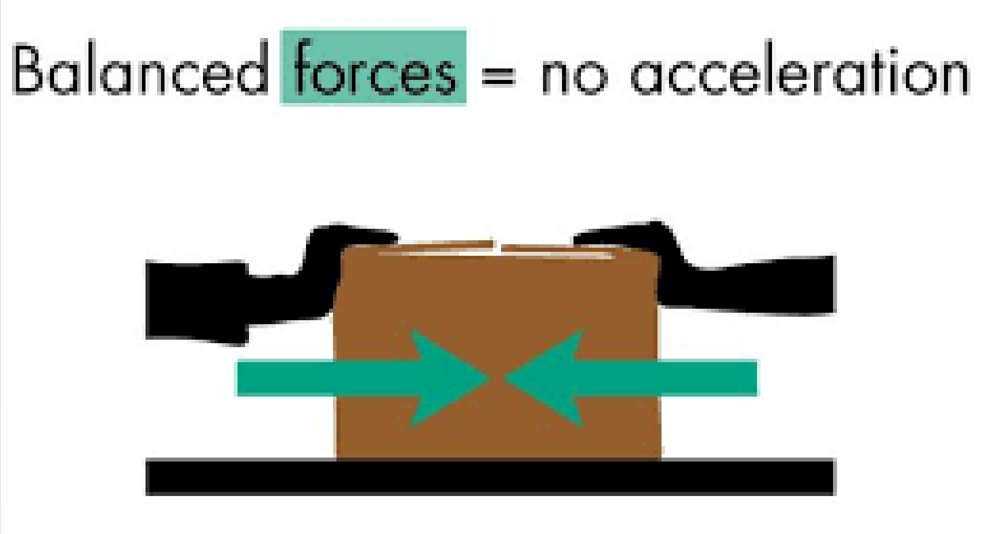
3. Students should be able to distinguish between an unbalanced force and a balanced force.

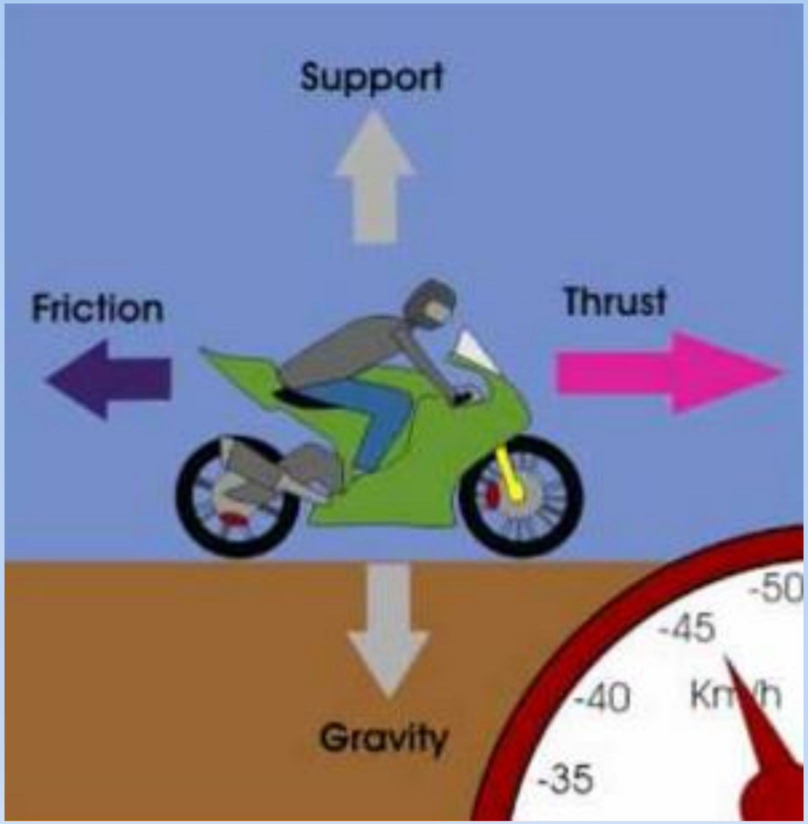
4. Students should be able to state that friction is an opposing force.

Force Affects Motion

How can force affect motion?

- ***Balanced Forces do not change motion (an object is at rest or constant speed) →***

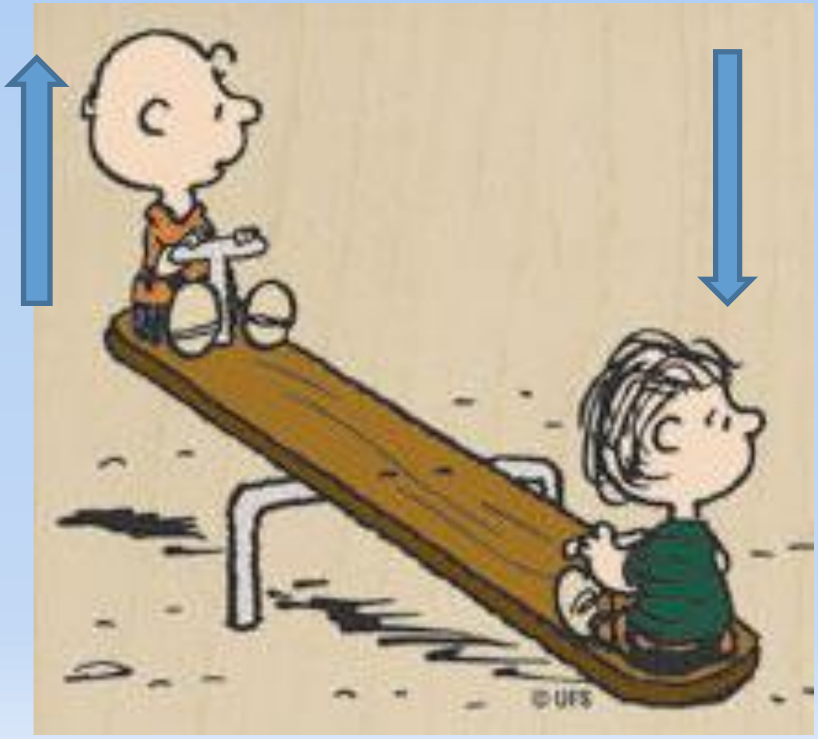




Force Affects Motion

How can force affect motion?

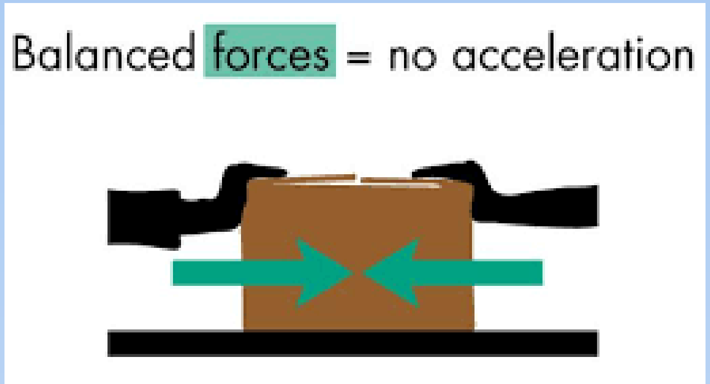
- ***Unbalanced forces produce a change in motion (acceleration) →***
- ***Unbalanced forces change the direction of motion →***



NET or Total Force

The NET or total force for balanced Forces is ZERO because the equal & opposite forces subtract out.

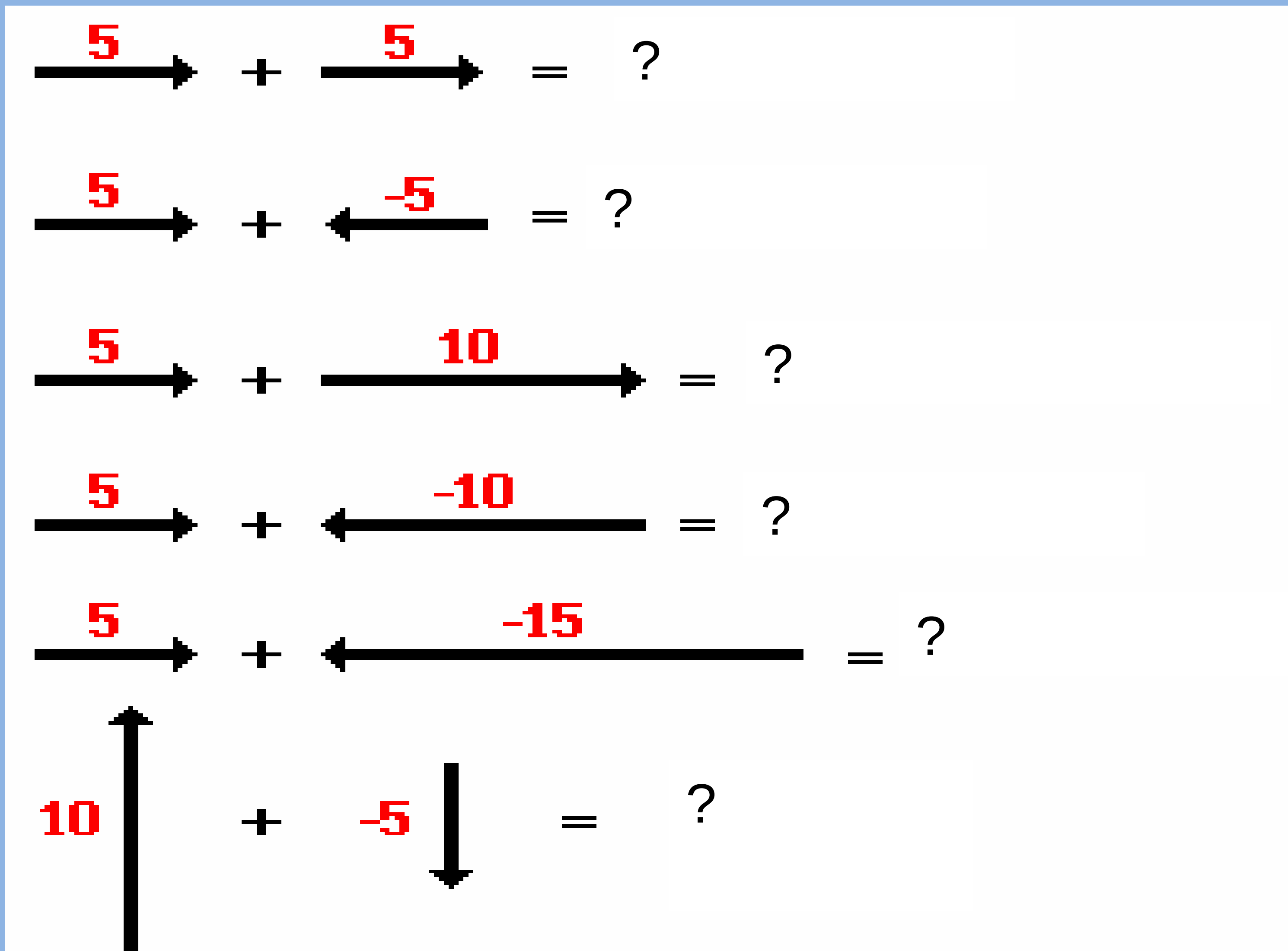
You can also say there is No Net force:



For unbalanced forces there will always be a net force. Unbalanced forces can be added or subtracted when applied to the same object depending on the direction of the applied force.

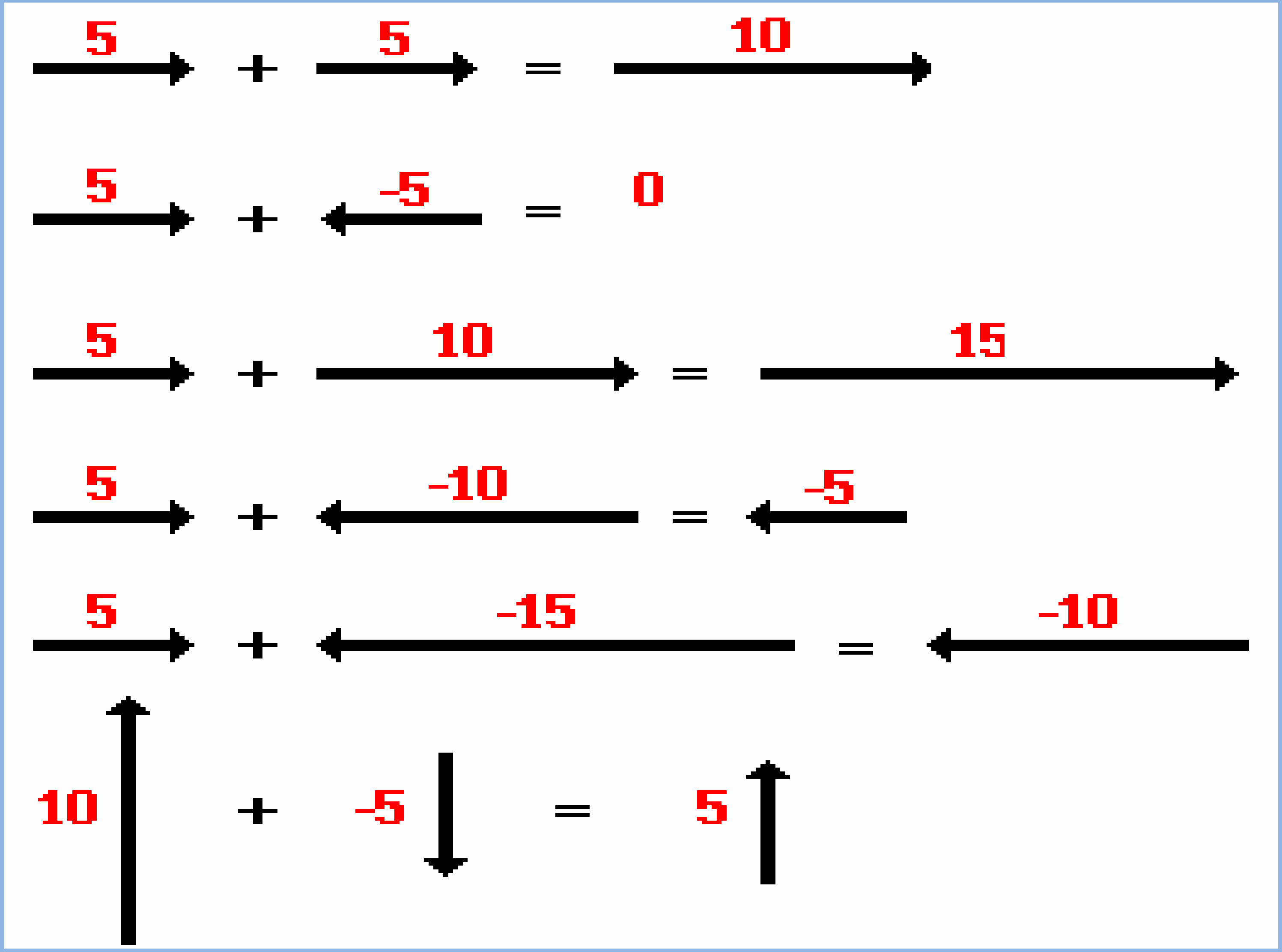
NET Force

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



NET Force

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



NET Force

Forces in the <u>same direction</u> combine by addition.

130 N + 120 N = ?

These are "UNbalanced" forces

Forces in <u>opposite directions</u> combine by subtraction.

130 N + 120 N ? 250 N = ?

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

These are **?** & **?** forces

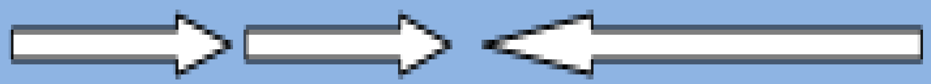
NET Force

Forces in the same direction combine by addition.

130 N + 120 N = 250 N

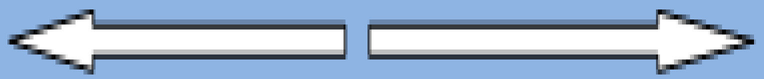
These are "UNbalanced" forces

Forces in opposite directions combine by subtraction.



130 N + 120 N – 250 N = 0

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

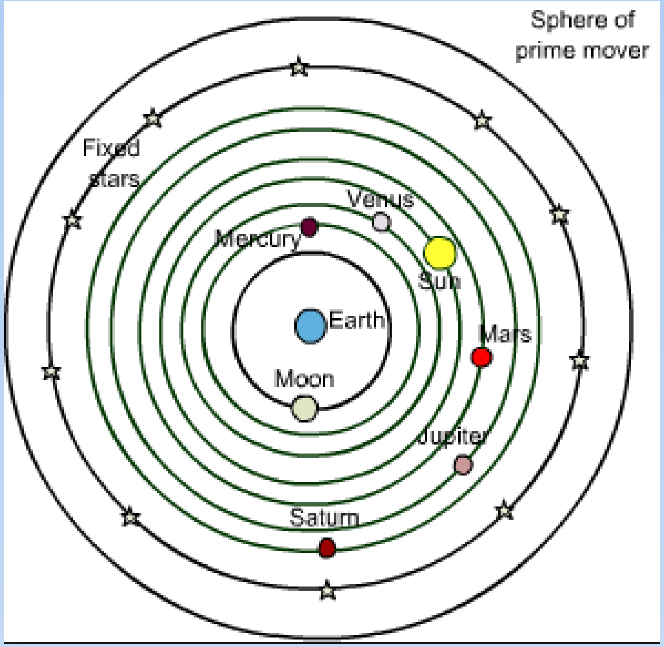


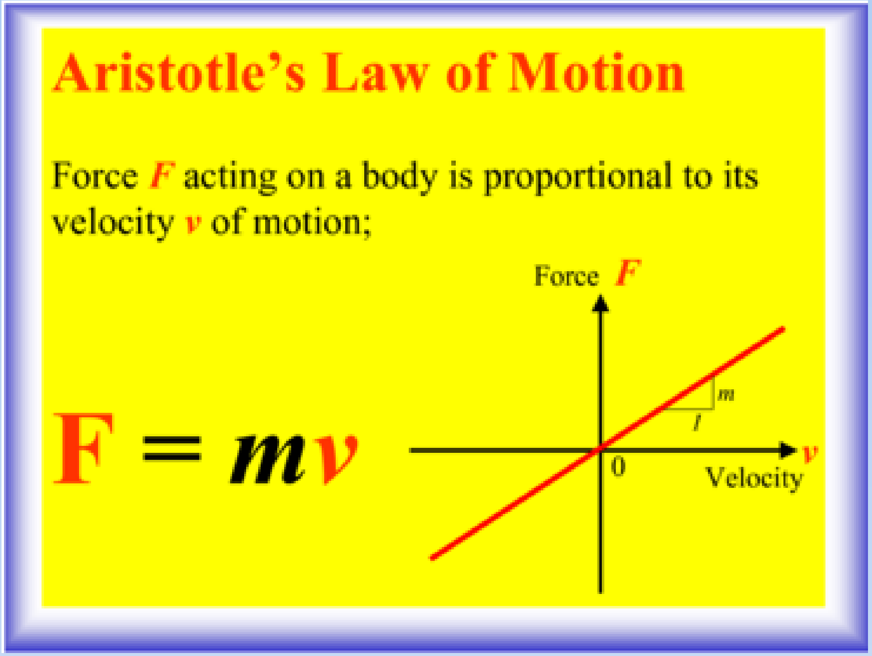
These are equal & opposite forces

History: Aristotle

~300 BC Philosopher, **not a scientist**, taught that:

- heavier objects fall faster than lighter objects
- Earth is the center of the universe
- All motion on earth is straight and linear

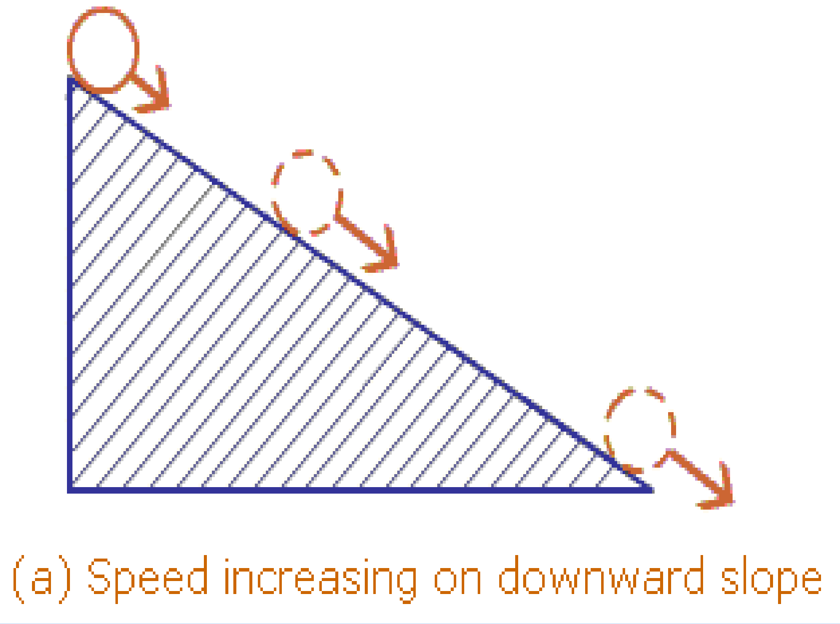




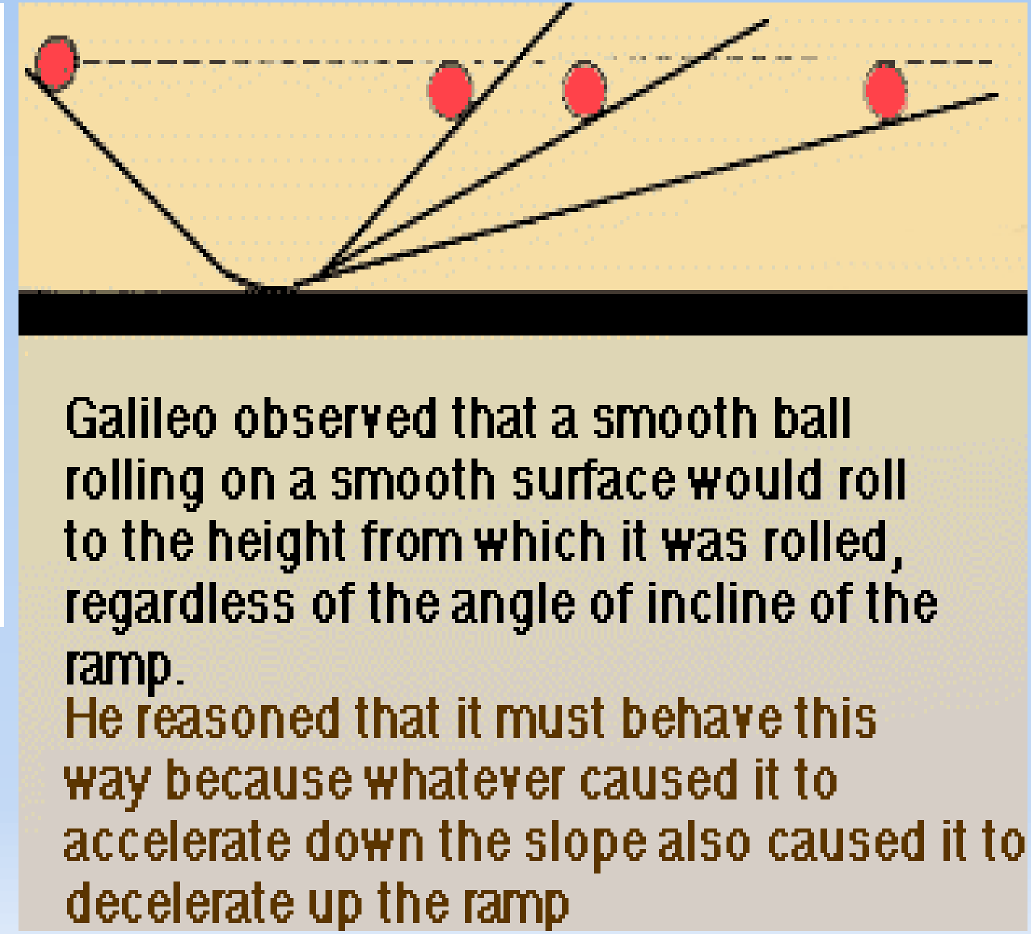
History: Galileo

Used the **Scientific Method** [*experimentation*] to show that:

moving objects continue to move unless acted upon by some force(s). He called the way objects behaved "**Inertia**."



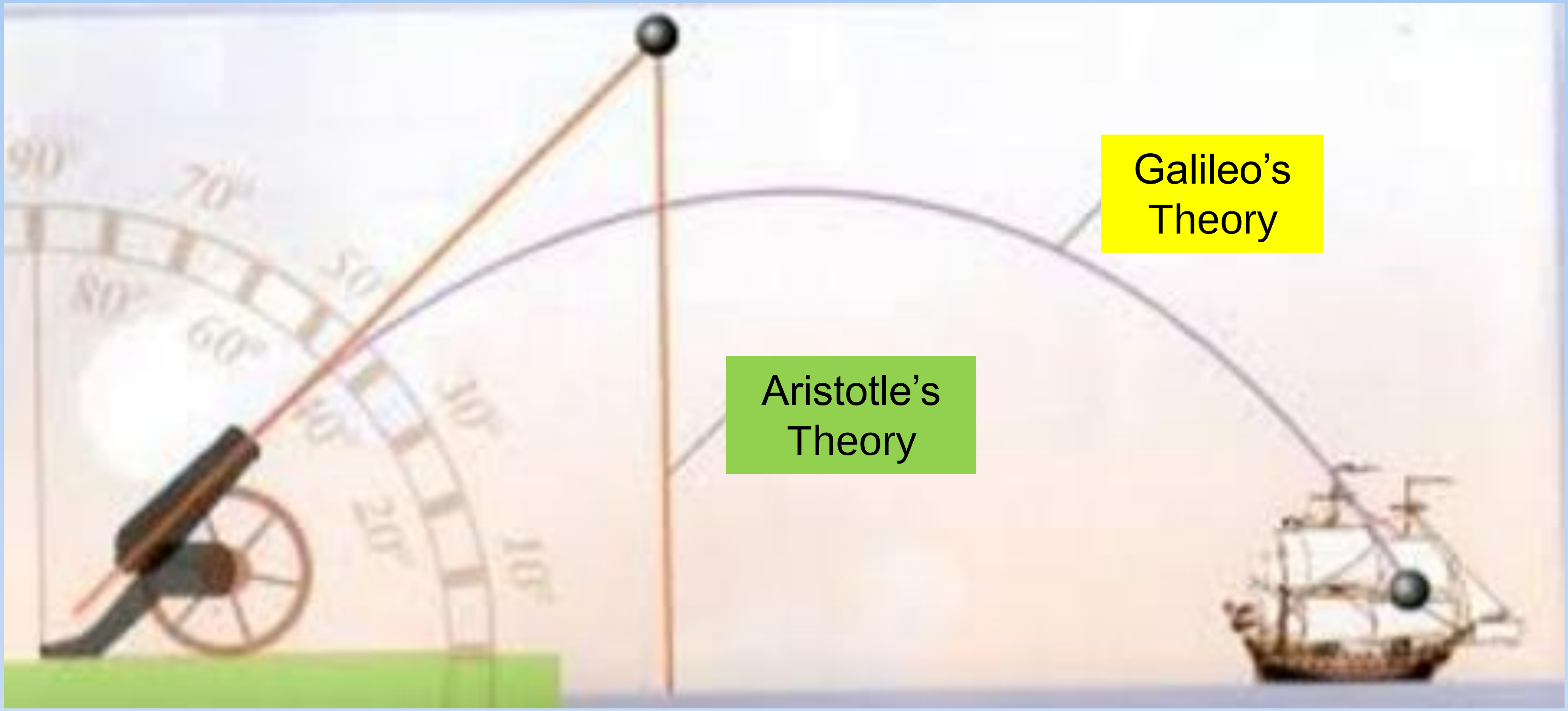
(b) Speed decreases on upward slope



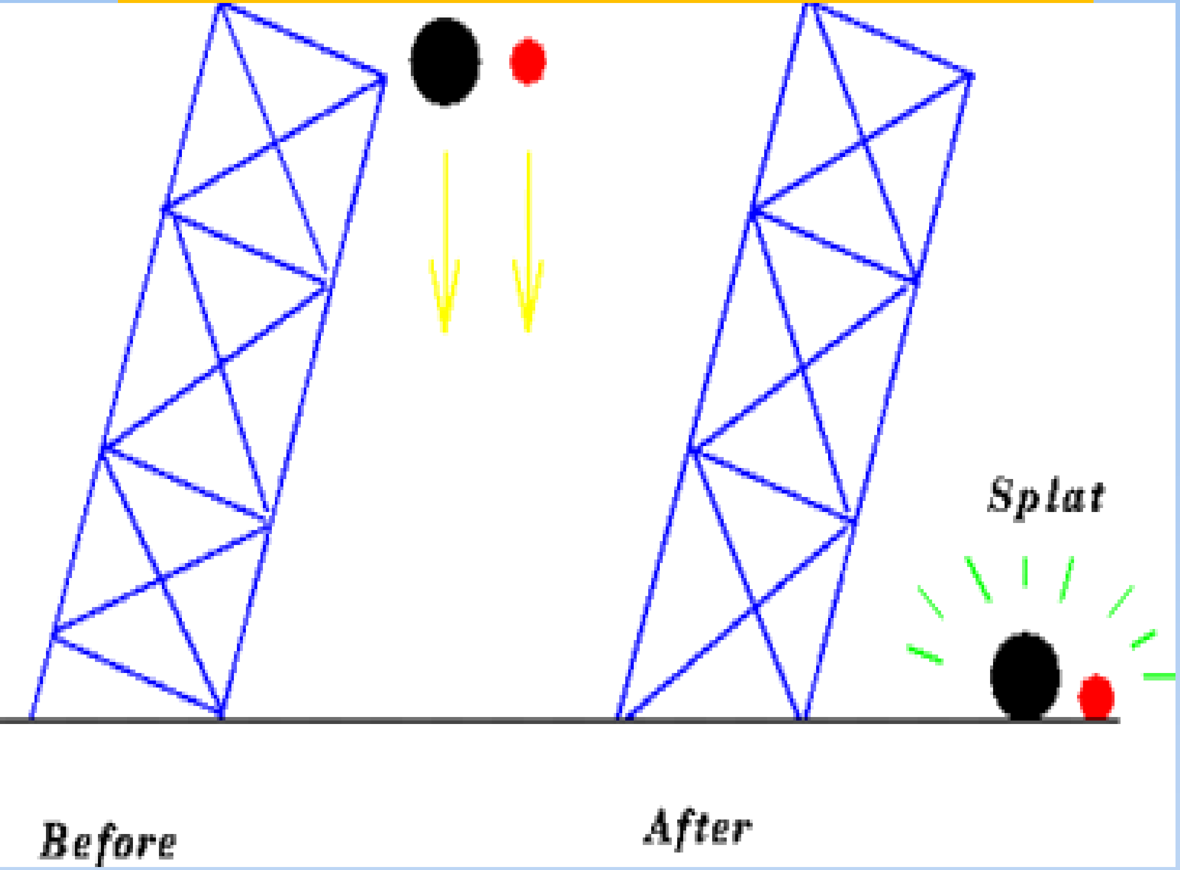
History: Galileo

Used the scientific Method [*experimentation*] to show that:

objects can demonstrate projectile motion (*objects do not just move in a straight and linear path … as Aristotle claimed*)



History: Galileo

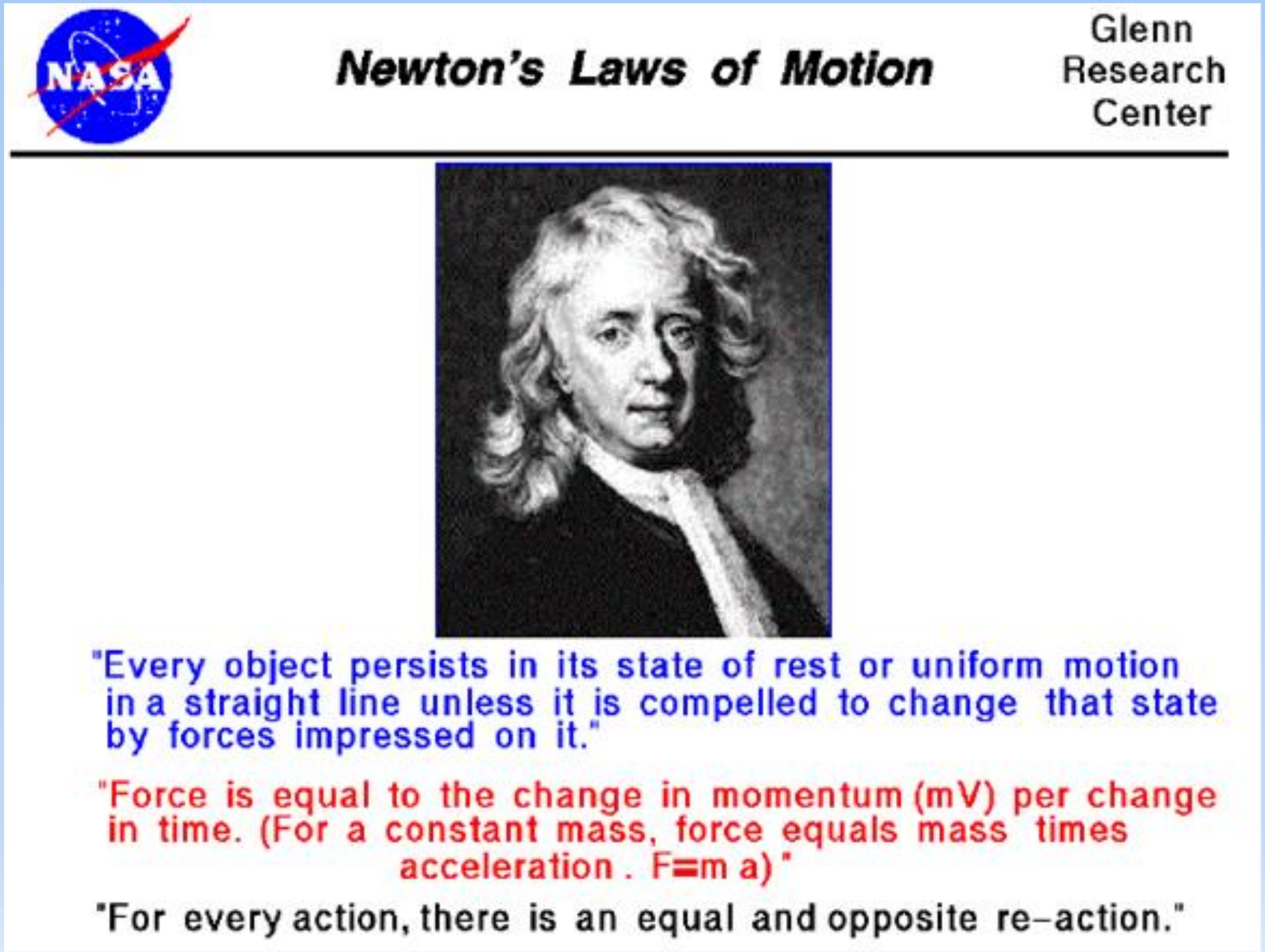


Galileo proved Aristotle wrong by dropping objects off the leaning tower of Pisa and accounting for air resistance. Heavier objects fell at the same rate as lighter objects due to gravity.

Consider philosophy versus science → Concepts versus facts. Man's knowledge versus God's truth. (1 Corinthians 8:1-2)

Sir Isaac Newton

(1642 – 1727) continued Galileo's work (*after Galileo died in 1642*) and became world famous for his three laws of motion.



Newton’ Laws of Motion Overview

Sports (3:12)

http://somup.com/cFXh0Un1k7

Hockey (5:22)

http://somup.com/cFXh04n1kN

Newton’s First Law

An **object at rest** will remain at rest and an **object in motion** will remain in motion at **constant velocity** unless acted upon by an **unbalanced** force.

Inertia is the tendency of matter to resist a change in motion.

- *Give examples of “inertia”*

THINK ABOUT IT

Newton's First Law

An **object at rest** will remain at rest and an **object in motion** will remain in motion at **constant velocity** unless acted upon by an **unbalanced** force.

Inertia is the tendency of matter to resist a change in motion.

- *Slamming on the brakes on an icy road … slip sliding away!*
- *Using seat belts in cars to avoid going through the windshield*
- *Roller coaster or "inertia" bumps – mesenteries inside our abdomen hold organs from hitting the sides of our body*
- *Going up/down in an elevator & the elevator stops … you can feel it*
- *Baseball players "round" the base rather than run at 'right' angles*

Newton's First Law

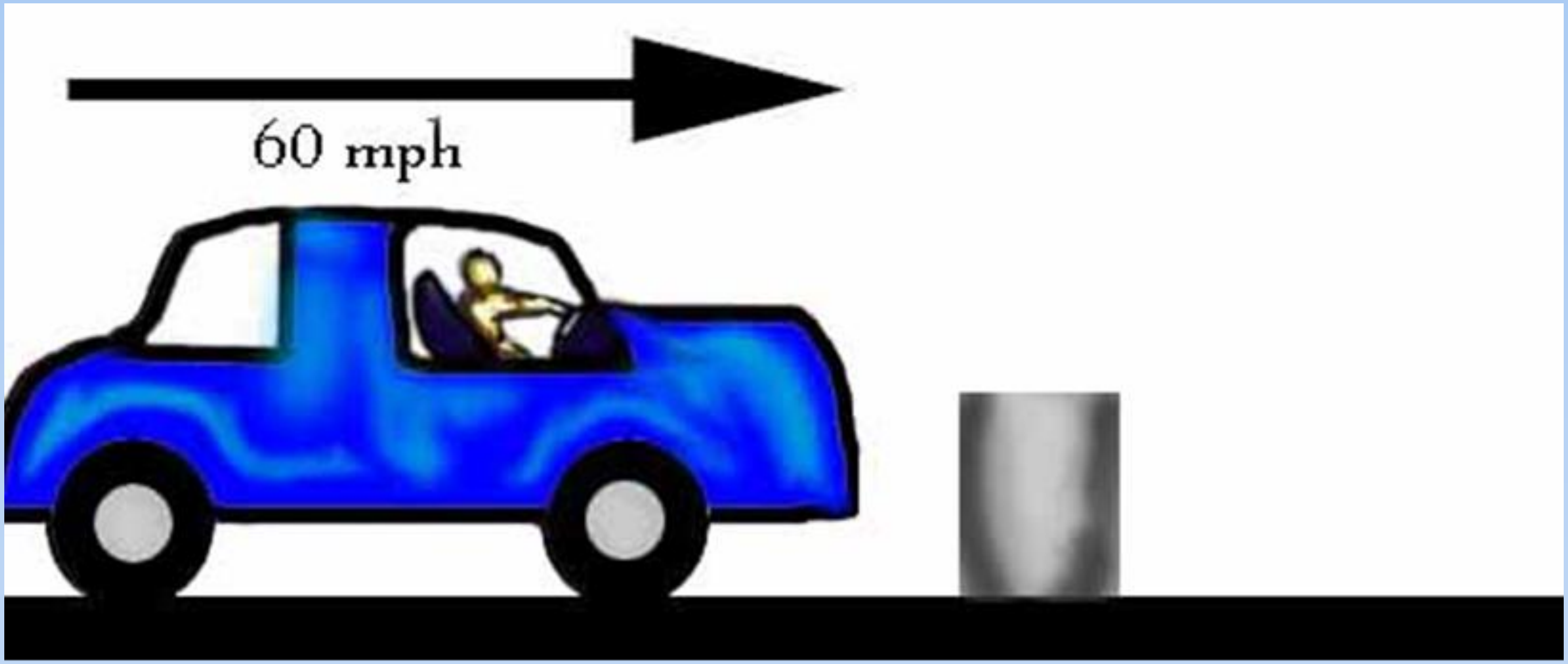
Inertia is directly related to **mass**. The greater the mass of an object, the greater its inertia or resistance to a change in motion.

	
A lot of inertia!	Very little inertia
Since the train is so huge, it is difficult to stop it once it is moving. It is difficult to change its speed. In fact, a large net force is required to change its speed.	*Since the soccer ball is so small, it is very easy to stop it once it is moving. A small net force is required to change its speed.*

Newton's First Law

QUICK CHECK

Describe the motion:



Newton's First Law

QUICK CHECK

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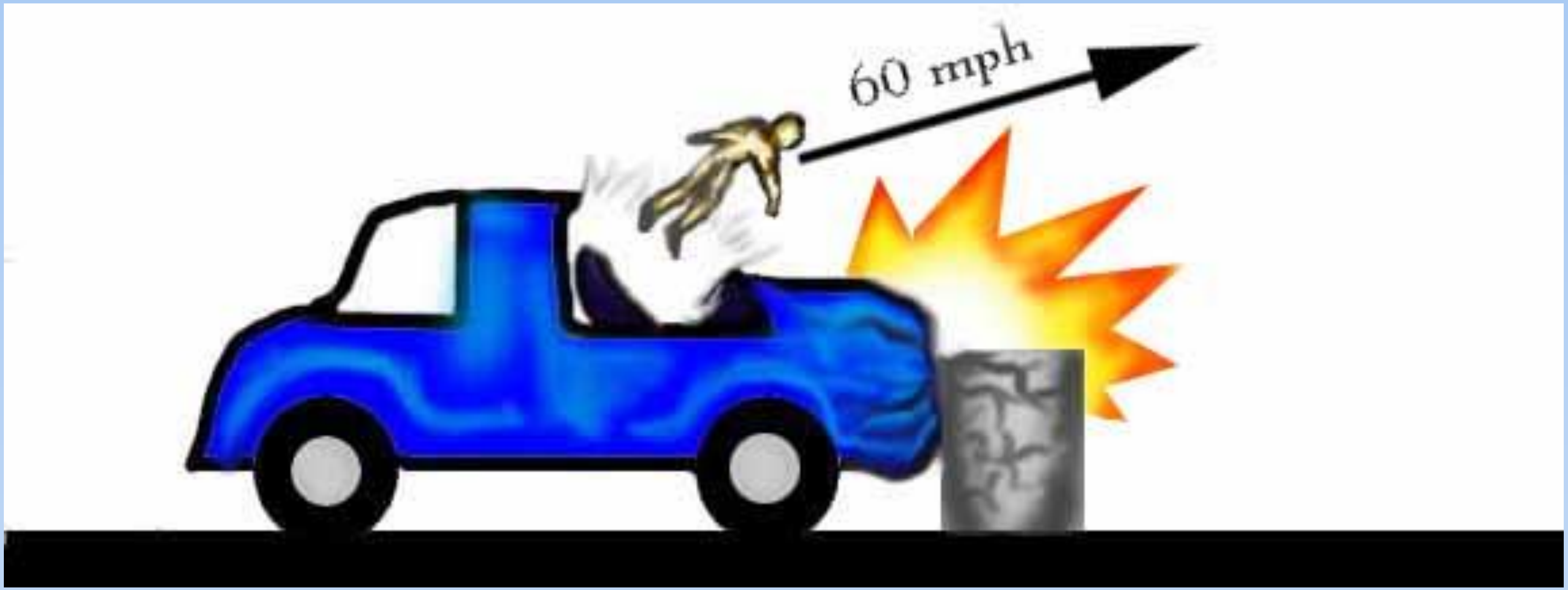

Newton's First Law

QUICK CHECK

Describe the motion:

Newton’s First Law

- Football: Newton’s 1st Law [3:37]

  http://somup.com/cFXh0gn1kP

  Ever seen the tablecloth trick?
  - Place a flat sheet of paper on a smooth table
  - Place a small container in the middle of the paper
  - Grab hold of one end of the paper tightly
  - Yank the paper QUICKLY … the object should not move

Newton's First Law of Motion

This crash sequence illustrates inertia. The test dummy continues its forward motion as the car slows and stops.

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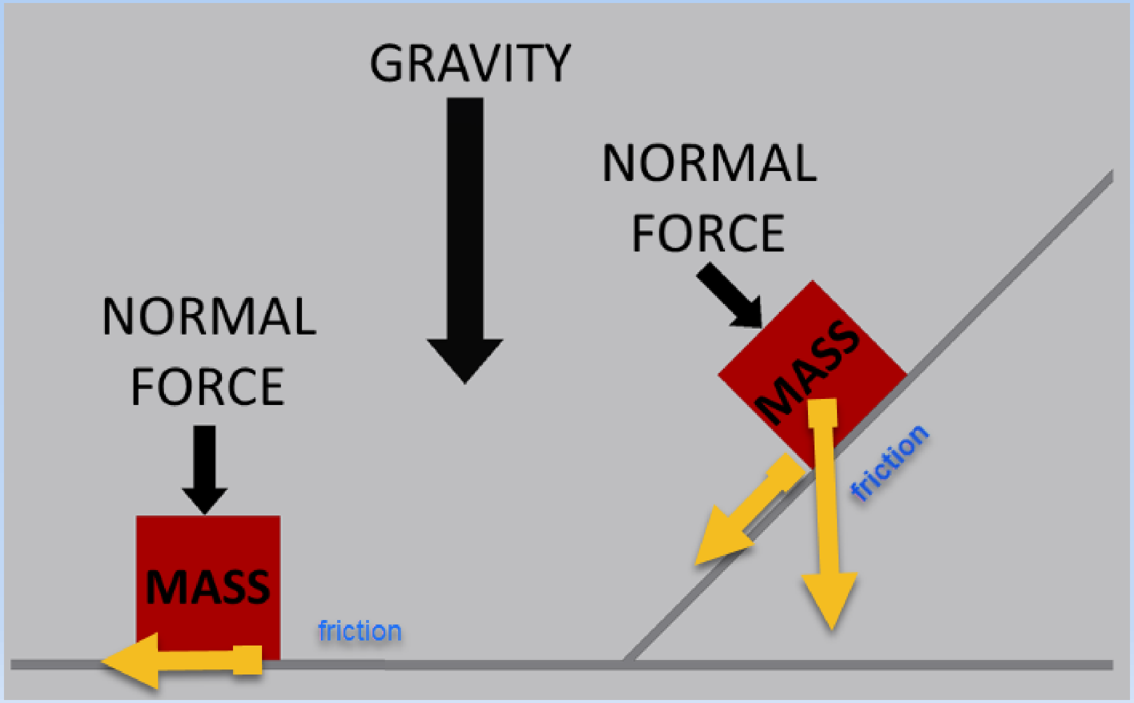
This crash sequence illustrates inertia. The test dummy continues its forward motion as the car slows and stops.

Forces that OPPOSE motion

Forces applied in the opposite direction to motion:

1. **Gravity →** **often opposes motion**
2. **Friction →** a force that always opposes motion, producing negative acceleration or "deceleration"



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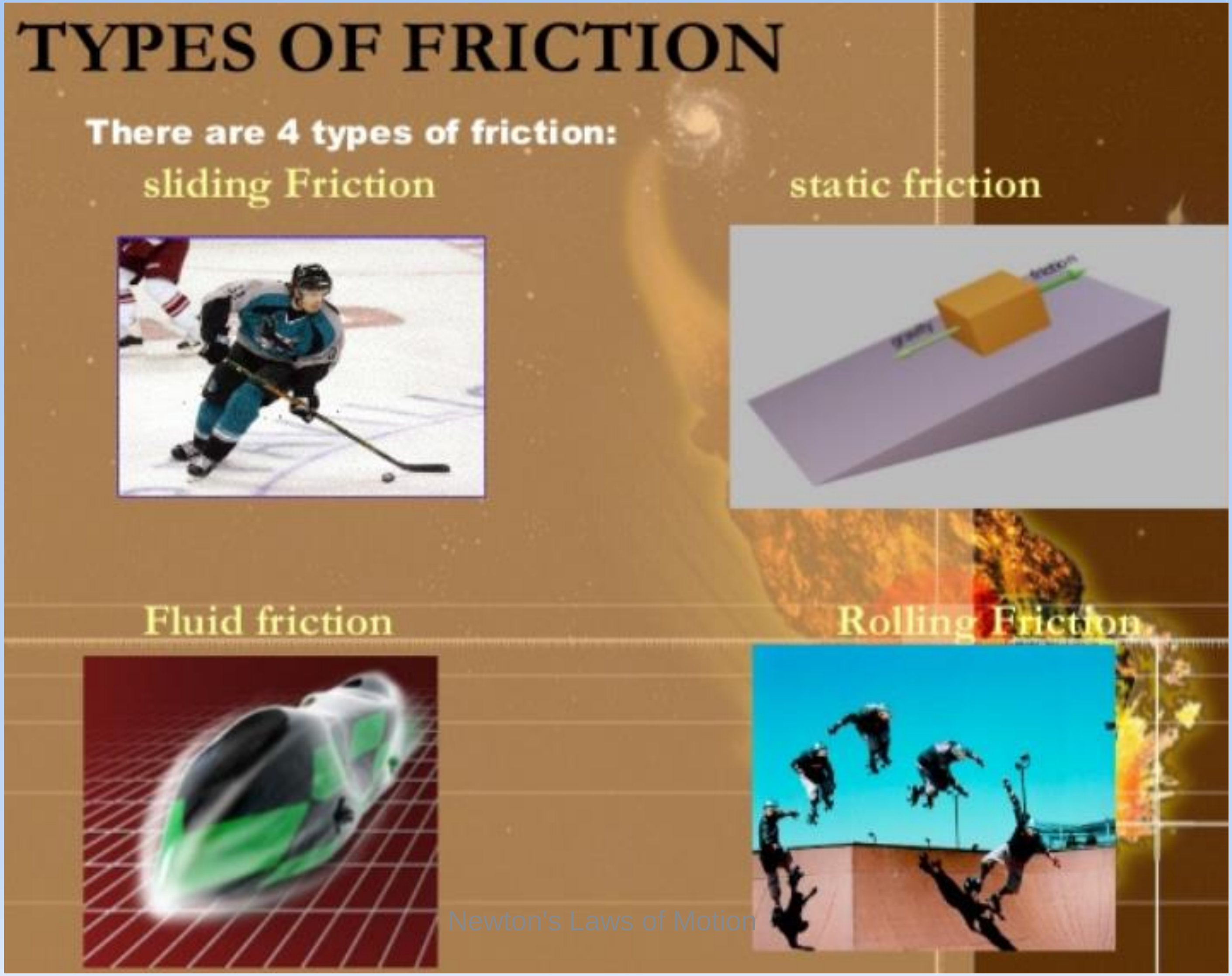

Forces that OPPOSE motion

Forces applied in the opposite direction to motion:

1. **Gravity → often opposes motion**
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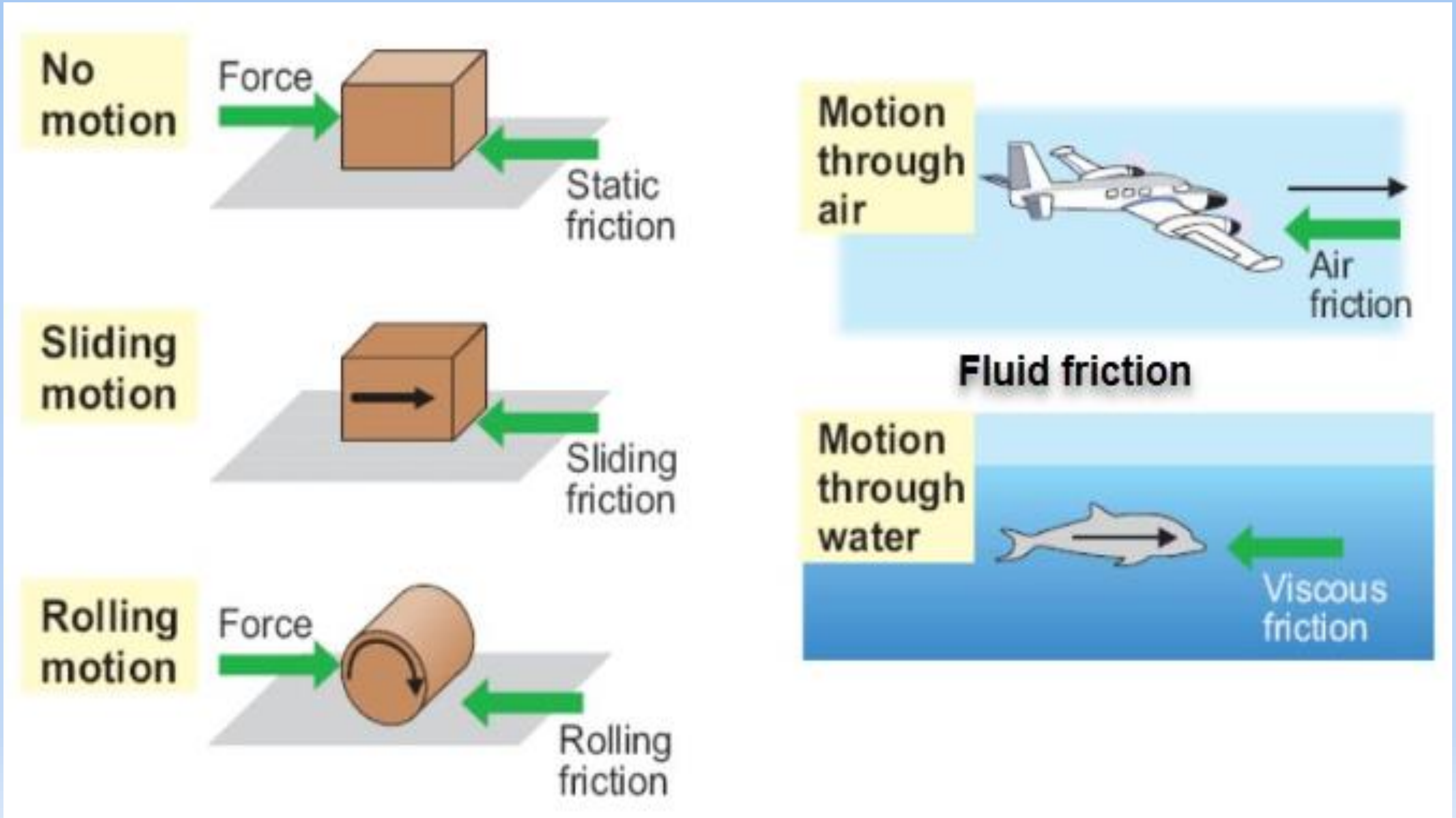
   The four kinds of friction & **how to reduce it**:

   - Sliding (*scuff feet on the floor*) - **lubrication**
   - Rolling (*roller blades, bicycles, cars*) – **ball bearings**
   - Fluid friction (*oil in crankcase, fish in water*) – **lubricate**, **streamline**
   - Static (*it is much harder to move a non-moving object than a moving one*)

"Kinetic" friction includes any object that is moving.

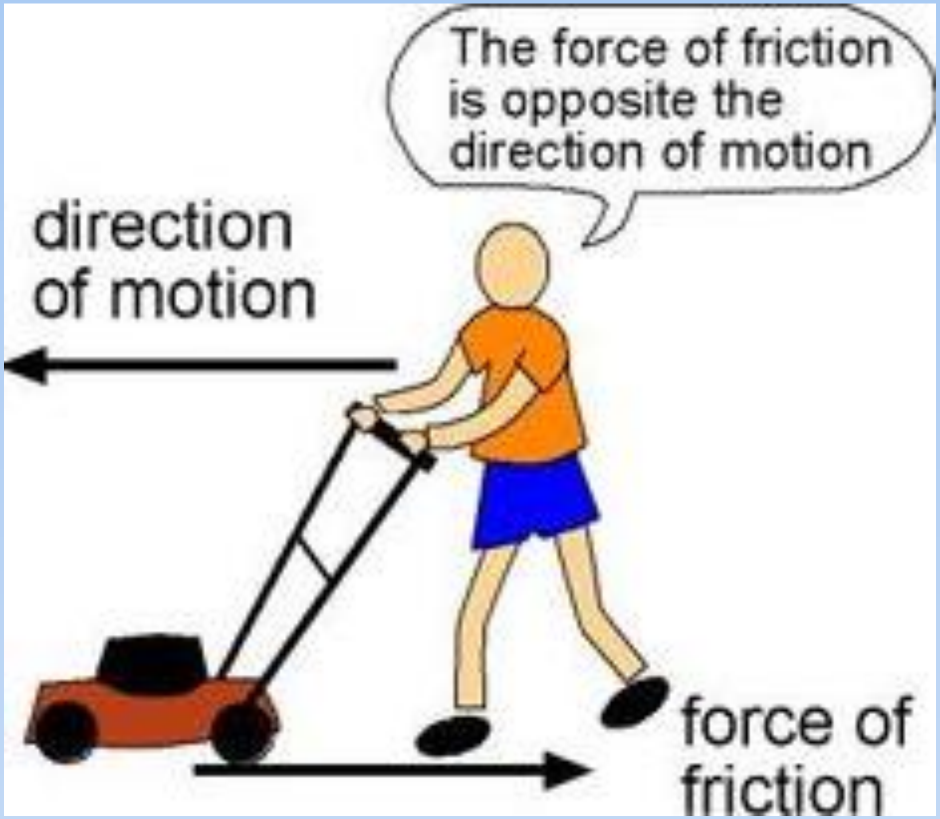
Forces that OPPOSE motion

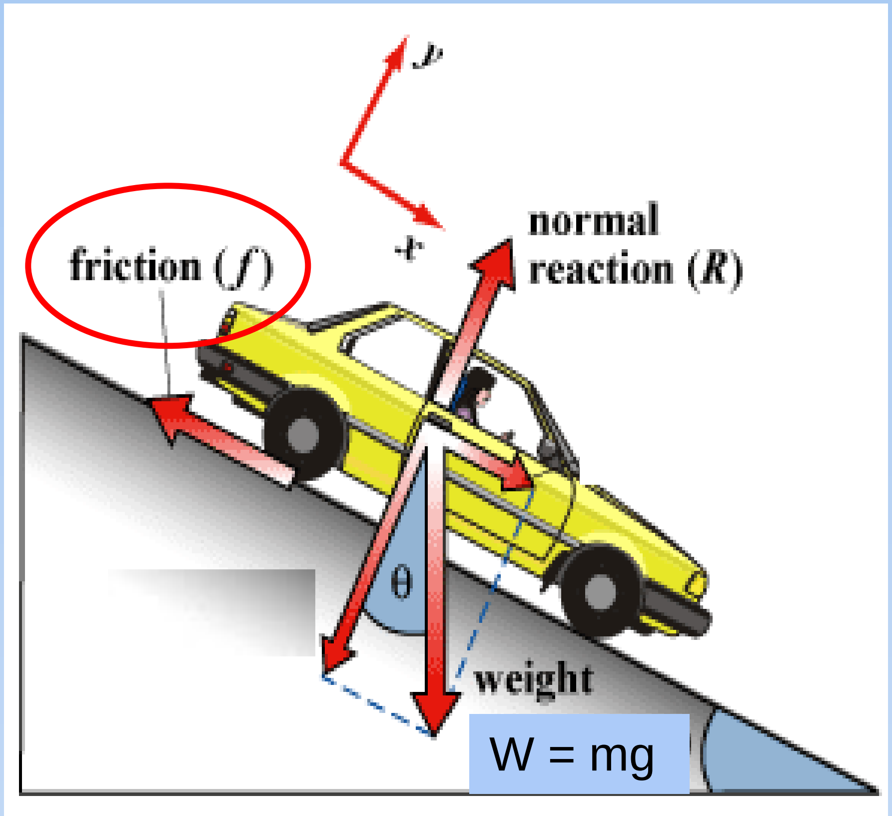
Forces applied in the opposite direction to motion:



Forces that OPPOSE motion

Friction & gravity play important roles in motion:





Net Force Involving Friction

If the power force of the car is 3500 N, the drag force (*due to the wind*) is 100 N and tire to road friction force is 200 N. What is the net force?

Net Force Involving Friction

If the power force of the car is 3500 N, the drag force (*due to the wind*) is 100 N and tire to road friction force is 200 N. What is the net force?

TRY IT

Net force is the sum of all the forces.

The drag and friction forces are in the same direction so we add them: 100 N + 200 N = 300 N.

The power force and frictional forces are in opposite directions so we subtract them: 3500 N – 300 N = 3200 N.

Friction Forces

1. How does the starting friction (*to move an object at rest*) of an object compare to the sliding friction (*to move an object already moving*)? [*e.g. think of pushing a car*]
2. What kind of <u>energy</u> is given off as a result of friction?
3. What do you think accounts for the difference between the starting friction and the sliding friction?
4. How does the surface area influence the sliding force of friction?
5. How does texture influence the sliding force of friction?
6. How does weight influence the sliding force of friction?
7. How does the steepness of a ramp influence the sliding force of friction?
8. List two situations in which friction can be helpful.

Friction Forces

1. How does the starting friction (to move an object at rest) compare to the sliding friction (to move an object already moving)?

   The starting friction is greater. This would be similar to pushing a stalled car into a parking lot. Initially, it takes a lot more force to get the car moving than to keep it moving at constant speed.

2. What kind of energy is given off as a result of friction?

   Heat energy is produced as a result of friction

3. What do you think accounts for the difference between the starting friction and the sliding friction?

   Inertia had to be overcome

4. How does the surface area influence the sliding force of friction?

   The greater the surface area, the greater the friction

Friction Forces

5. How does texture influence the sliding force of friction?

   A rougher texture/surface produces greater friction

6. How does weight influence the sliding force of friction?

   The weight increases the pressure (force per unit area) on the contact surface. Therefore, the force of friction increases with the weight of an object.

7. How does steepness of a ramp influence the sliding force of friction?

   The steeper a ramp, the LESS sliding friction exists. This is because the steeper the slope, the more the gravity component overcomes the horizontal friction component. It's easier to fall off a steep slope.

8. List two situations in which friction can be helpful.

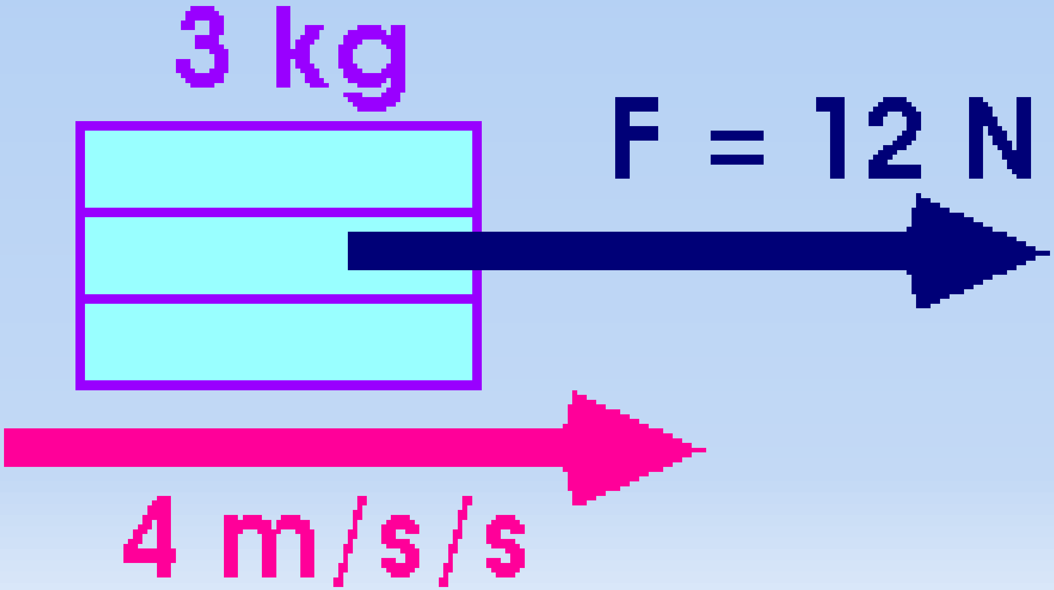
   … brakes on vehicles; nonslip bath mats; rubber soles on boots, grabbing and holding objects, objects stay in position, etc.

Newton's Second Law

Describes how force, acceleration, and mass are related. Force equals mass times acceleration.

To overcome inertia, one accelerates / decelerates … when accelerating, one feels an **unbalanced** force.

To accelerate a 3 kg mass to 4 m/s/s requires 12 N of force: ***f = ma***



Newton's Second Law

1. ***Racing a grocery cart down the isles – the harder you push, the faster it goes***

2. ***Hitting a 0.06 kg tennis ball with a tennis racket versus throwing the ball like a pitcher (thrown about 70 mph vs. hit about 130 mph)***

70 mph x 1.6 km/mi = 112 km/hr = 112,000 m/hr x 1 hr/3600 s = 31.1 m/s

Accelerated by the racket for ~0.005 s → *a = (vf – vi) / t*

a = 6,220 m/s/s

F = ma (0.06 kg)(6,222 m/s/s) = <u>373 N</u>

130 mph = 208 km/hr … F = ma (0.06 kg)(11,555 m/s/s) = <u>693 N</u>

3. ***Tractor pulls or monster trucks use much more force to accelerate than smaller vehicles***

Newton’s Second Law

The Legend of the Tortoise and the Hare

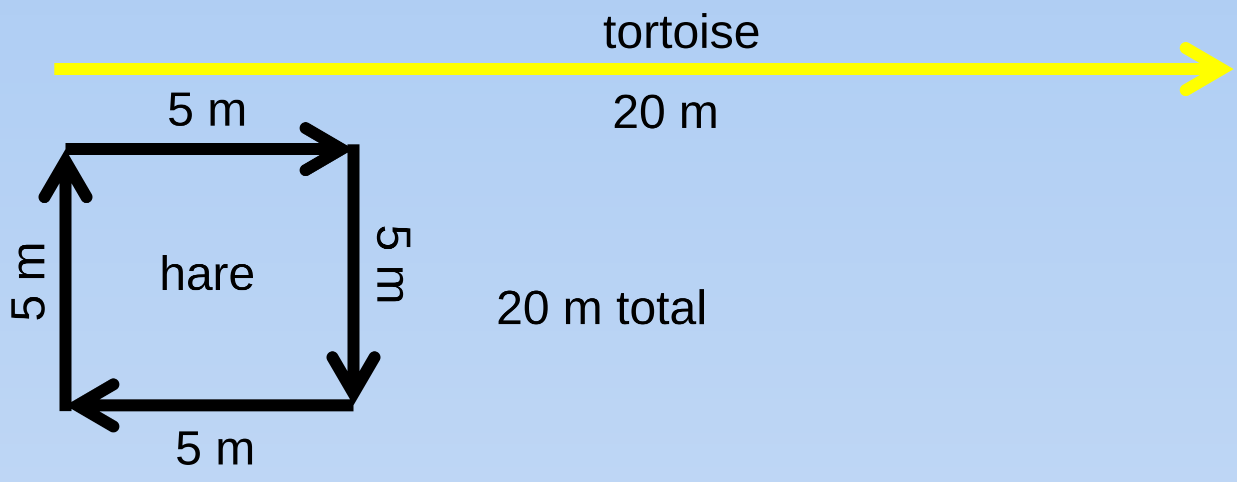
The Tortoise really wins!

Can you show using Physics and not logic or guessing how the tortoise can win?

The Legend of the Tortoise and the Hare

The Tortoise really wins!

- Pick a slower student to represent the "tortoise" and a faster student to represent the "hare"
- Measure off a 20 meter straight track and line up the "tortoise"
- Measure off a square with sides of 5 meters each & line up the "hare"
- Start the race … most likely the tortoise will win



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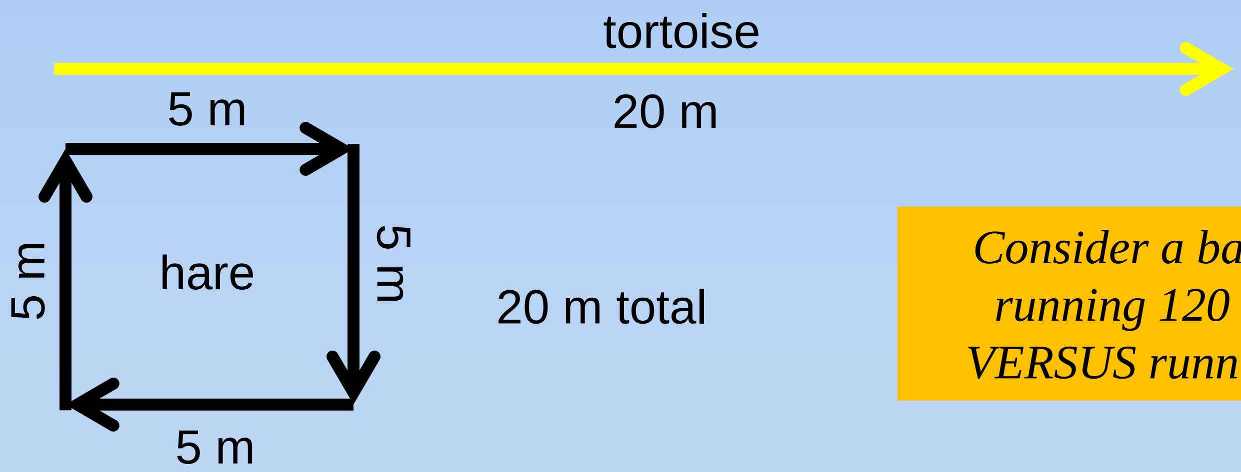
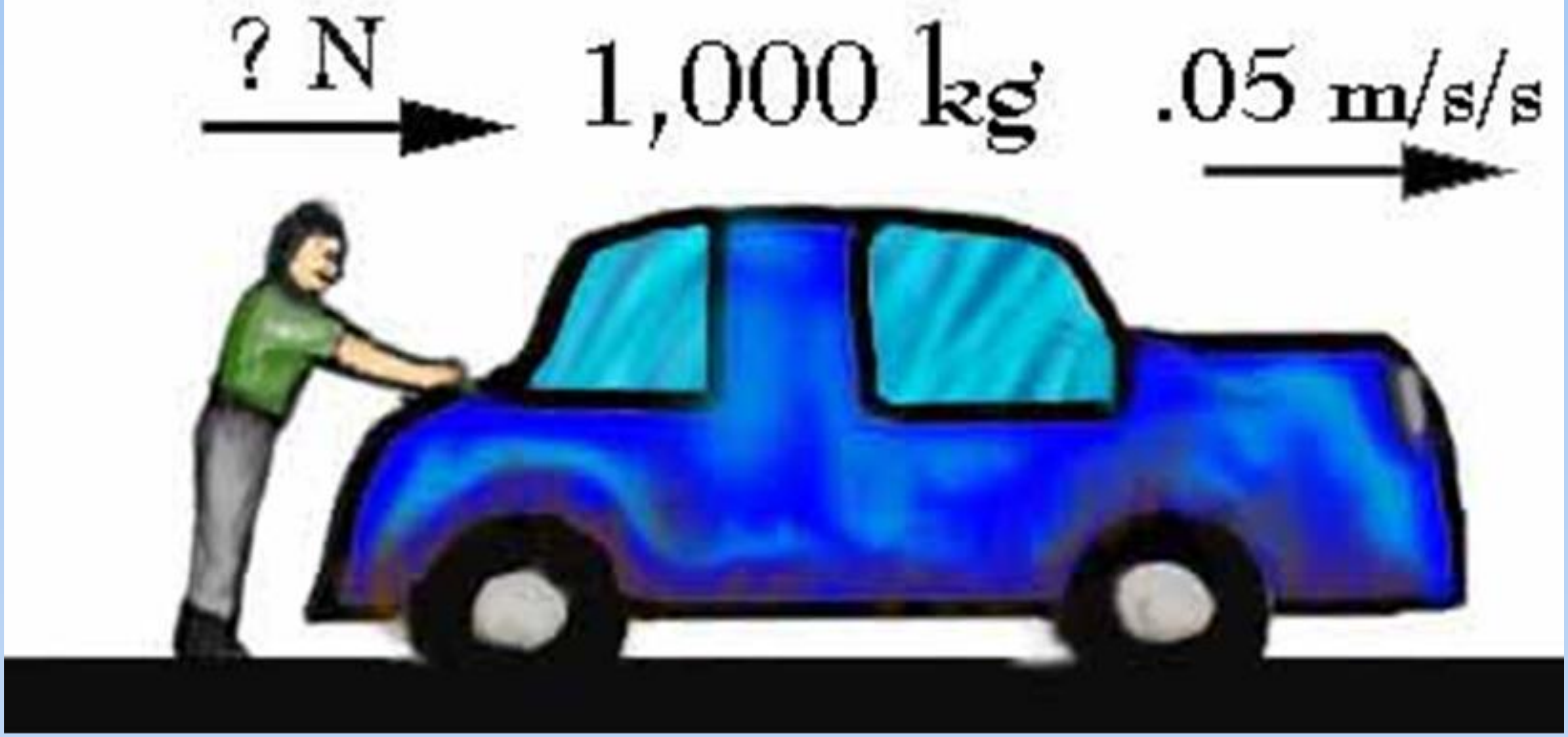


Consider a baseball player running 120 feet straight VERSUS running the bases.

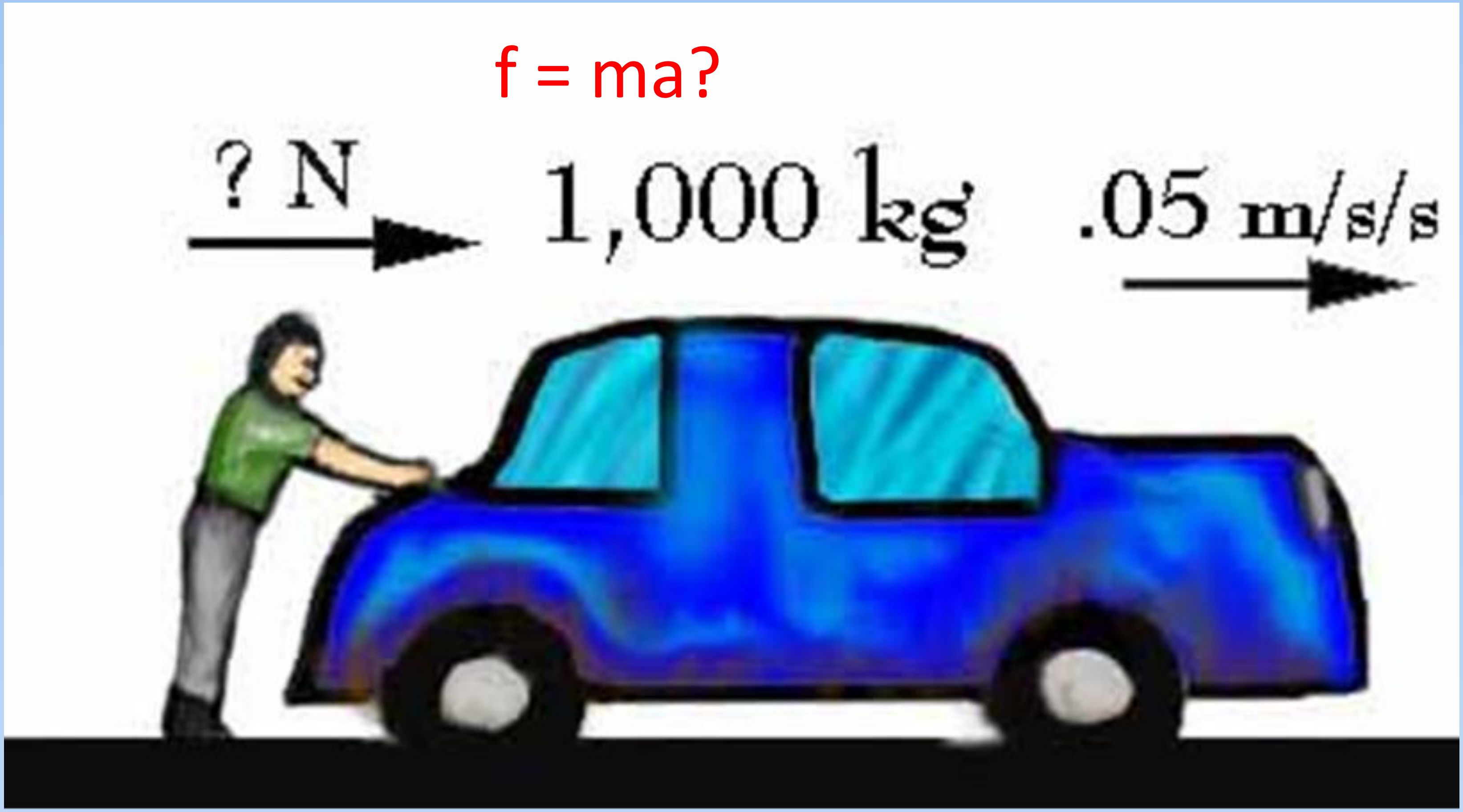
The “hare” has to accelerate & decelerate to almost a stop at FOUR different points versus **the “tortoise” only at ONE point**. Therefore, the “hare” uses a lot more energy covering the same distance.

Newton's Second Law

f = ma?

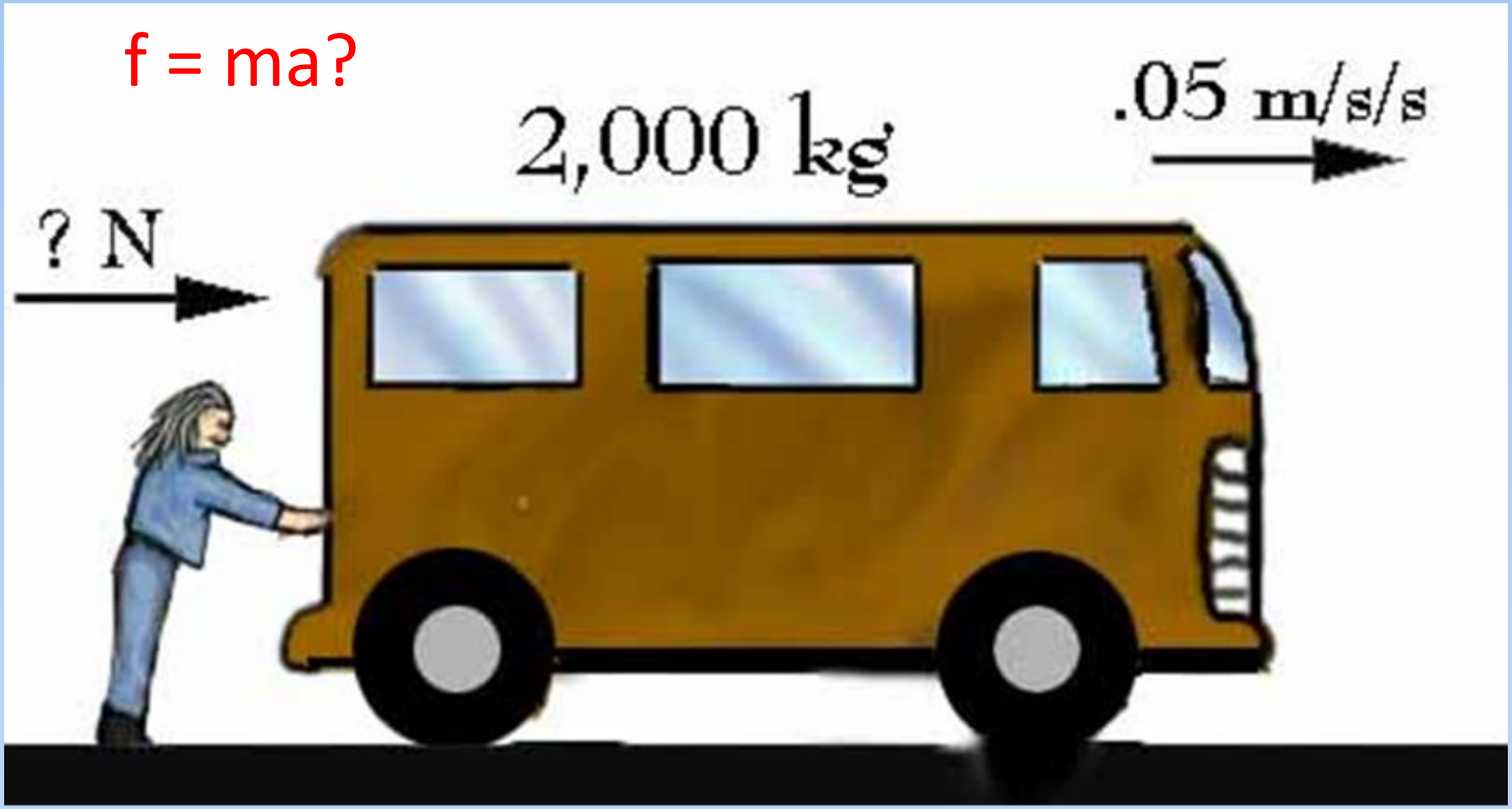


Newton's Second Law

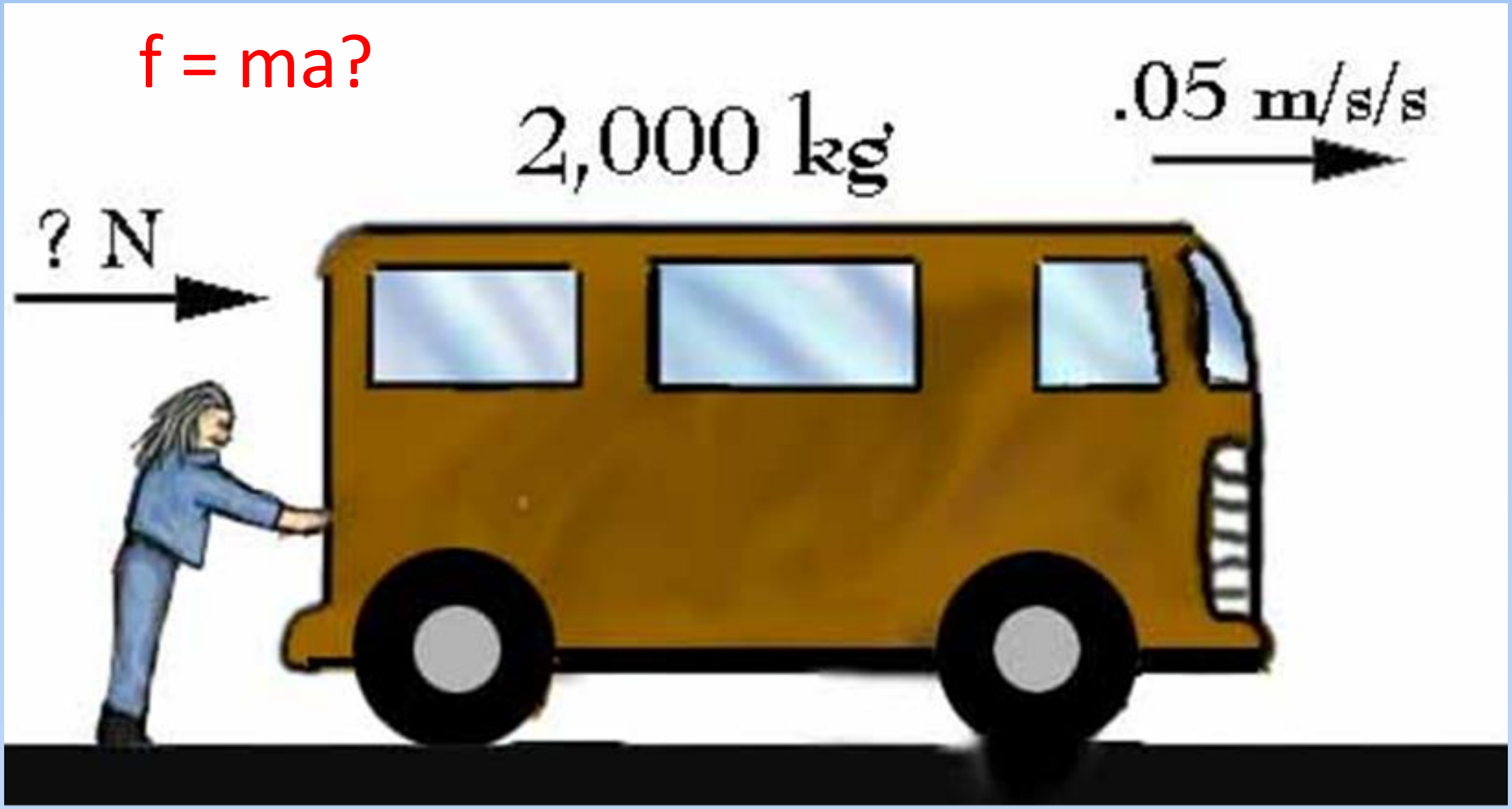


$f = ma \rightarrow 1{,}000\ Kg \times 0.05\ m/s/s =$ 50 N

Newton's Second Law



Newton's Second Law



$f = ma \rightarrow 2{,}000\ Kg \times 0.05\ m/s/s =$ 100 N

Newton's Second Law

- Football: Newton's 2nd Law [3:37]

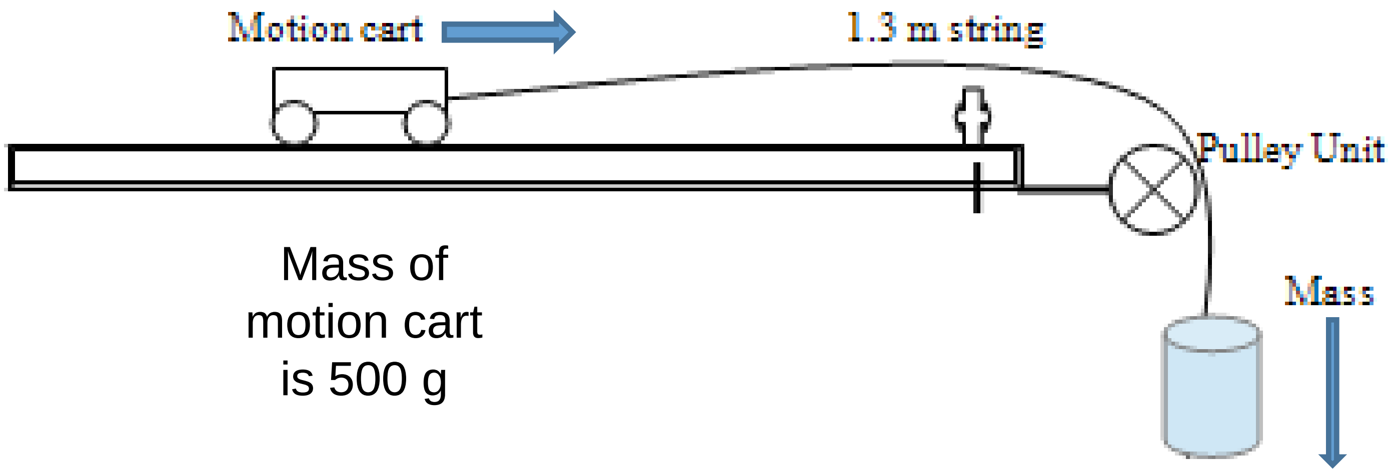
http://somup.com/cFXh05n1kR

Place Kicking

http://somup.com/cYVZDwfWoH

Car Racing (1:15)

Calculate the Force in each case as shown below:

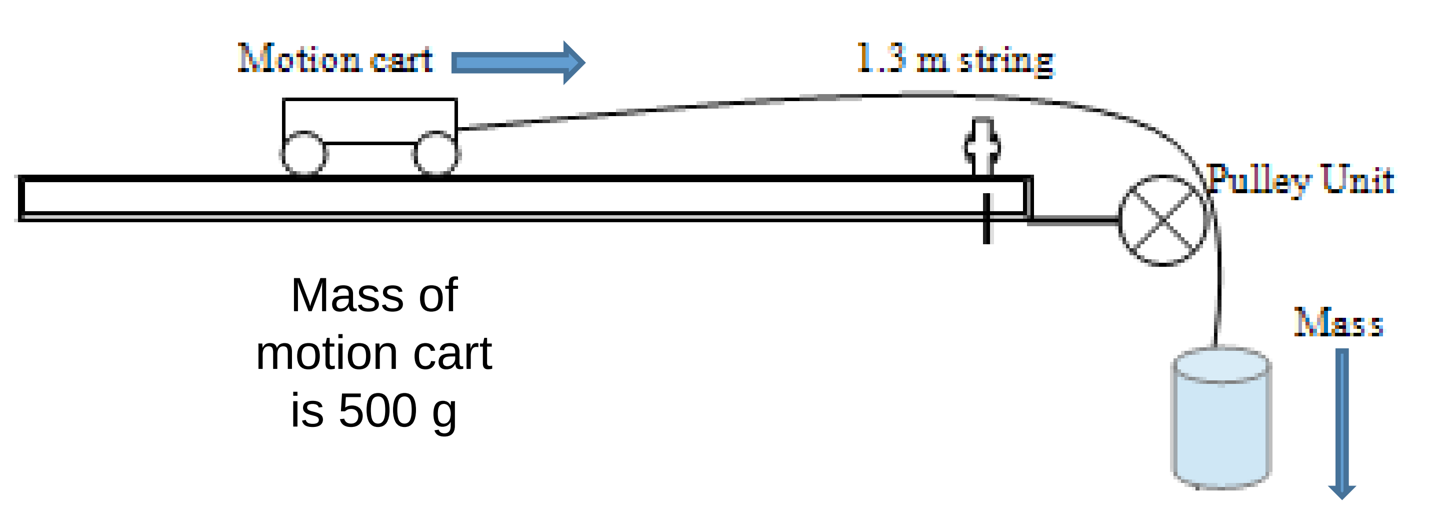


Mass of motion cart is 500 g

A 20 g mass falls so that the motion cart moves 1 meter in 2.2 s accelerating 0.4 m/s^2.

What would happen if we drop a heavier mass?

Calculate the Force in each case as shown below:

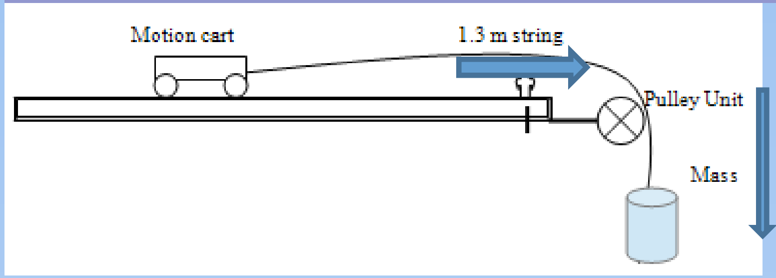


A 20 g mass falls so that the motion cart moves 1 meter in 2.2 s accelerating 0.4 m/s^2.

A 50 g mass falls so that the motion cart moves 1 meter in 1.4 s accelerating 1.0 m/s^2.

A 100 g mass falls so that the motion cart moves 1 meter in 1.1 s accelerating 1.7 m/s^2.

Calculate the Force in each case as shown below:



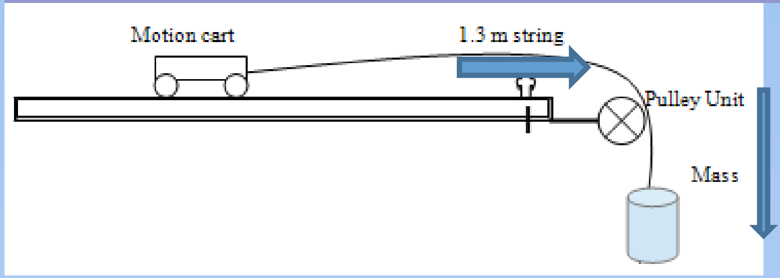
A 20 g mass falls so that the motion cart moves 1 meter in 2.2 s accelerating 0.4 m/s^2.

A 50 g mass falls so that the motion cart moves 1 meter in 1.4 s accelerating 1.0 m/s^2.

A 100 g mass falls so that the motion cart moves 1 meter in 1.1 s accelerating 1.7 m/s^2.

What is the relationship between mass and acceleration?

Calculate the Force in each case as shown below:



A 20 g mass falls so that the motion cart moves 1 meter in 2.2 s accelerating 0.4 m/s².

A 50 g mass falls so that the motion cart moves 1 meter in 1.4 s accelerating 1.0 m/s².

A 100 g mass falls so that the motion cart moves 1 meter in 1.1 s accelerating 1.7 m/s².

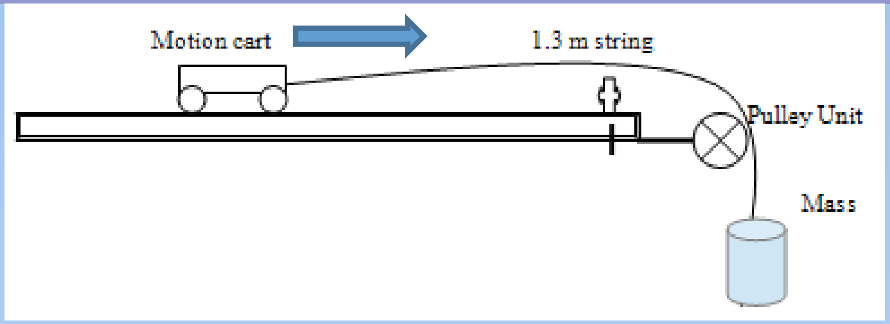
What is the relationship between mass and acceleration?

It is a direct relationship … as mass increases, acceleration increases:

Calculate the Force in each case as shown below:

TRY IT

Mass of motion cart is 500 g



$$f = ma$$

We are looking for the force to move the motion cart. We can also use "Weight" as the force (W = mg) based on the falling masses.

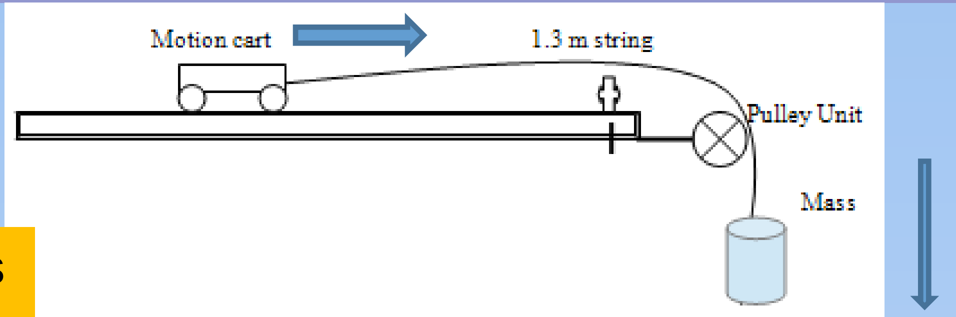
$f_{20\ g} =$

$f_{50\ g} =$

$f_{100\ g} =$

Calculate the Force in each case as shown below:

TRY IT



Mass of motion cart is 500 g = 0.5 kg

$$f = ma \quad \ldots W = mg$$

$$f_{20\,g} = ma \rightarrow f_{20\,g} = (0.5\ kg)(0.4\ m/s^2) = 0.2\ N$$

$$W_{20\,g} = mg = (0.02\ kg)(10\ m/s^2)$$

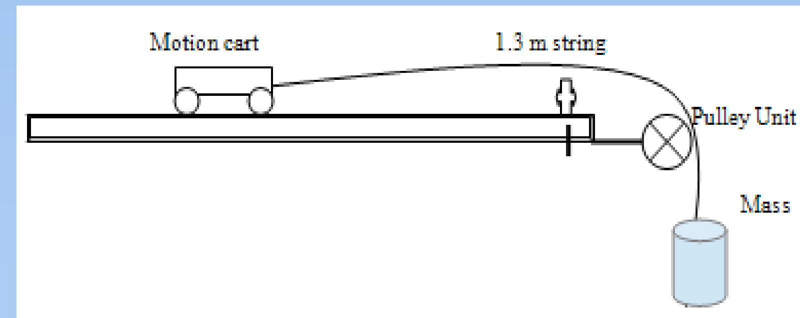
$$f_{50\,g} = ma \rightarrow f_{50\,g} = (0.5\ kg)(1.0\ m/s^2) = 0.5\ N$$

$$W_{50\,g} = mg = (0.05\ kg)(10\ m/s^2)$$

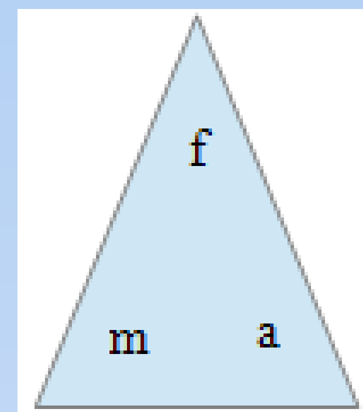
$$f_{100\,g} = ma \rightarrow f_{100\,g} = (0.5\ kg)(1.7\ m/s^2) = 0.9\ N$$

$$W_{100\,g} = mg = (0.1\ kg)(10\ m/s^2)$$

Force Applied (N)	Mass of Motion Cart (kg)	Acceleration of motion cart
0.2 N		
0.5 N	0.5 kg	
1.0 N		



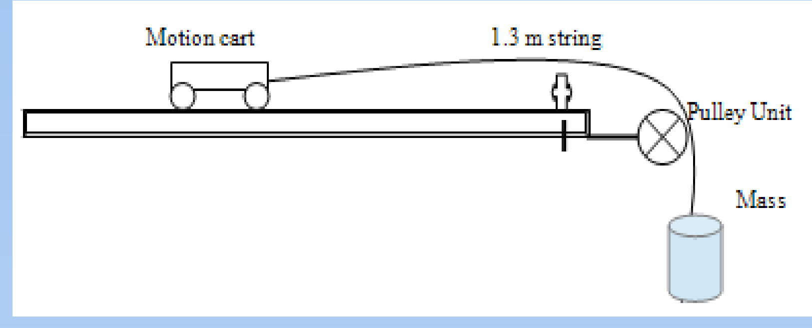
Using the same set up but given the force and mass calculate the acceleration produced in each case.



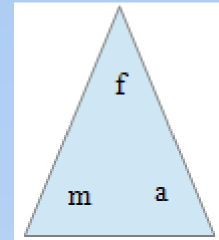
Force Applied (N)	Mass of Motion Cart (kg)	Acceleration of motion cart
0.2 N		0.4 m/s2
0.5 N	0.5 kg	1.0 m/s2
1.0 N		2.0 m/s2

FORCE of motion cart is 0.5 kg x 10 N/kg = 5 N because of weight (mg)

TRY IT



Calculate the acceleration produced in each case. (*Notice the triangle to the right*.)



Lightest Mass

$a = f/m$

$= 0.2\ N / 0.5\ kg$

$= 0.4\ m/s^2$

2nd Lightest Mass

$a = f/m$

$= 0.5\ N / 0.5\ kg$

$= 1.0\ m/s^2$

Heaviest Mass

$a = f/m$

$= 1.0\ N / 0.5\ kg$

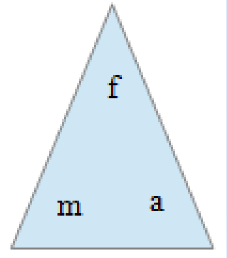
$= 2.0\ m/s^2$

Net Force Involving Friction

TRY IT

We already calculated that if the power force of the car is 3500 N and the drag (due to wind) is 100 N and tire to road friction is 200 N, the net force is 3200 N.

Suppose the car has a mass of 1600 kg. How much acceleration can the car have?



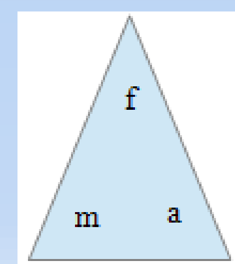
TRY IT

Net Force Involving Friction

We already calculated that if the power force of the car is 3500 N and the drag (due to wind) is 100 N and tire to road friction is 200 N, the net force is 3200 N.

Suppose the car has a mass of 1600 kg. How much acceleration can the car have?

$a = f/m \rightarrow 3200\ N / 1600\ Kg = 2\ m/s^2$



QUICK CHECK

Match the term with the description:

1. **Scientist who used experimentation related to force & motion.**
2. **Scientist who introduced laws describing force & motion.**
3. **Philosopher who made many discoveries through observation & logical reasoning.**

- **A. Aristotle**
- **B. Galileo**
- **C. Newton**

4. **A measure of the mass of an object … the tendency to resist change.**
5. **Related to the mass of an object and the acceleration it produces.**
6. **An objects motion changes (slow down, speed up, direction)**

- **A. Acceleration**
- **B. Force**
- **C. Inertia**

QUICK CHECK

Match the term with the description:

Answers

1. **Scientist who used experimentation related to force & motion.** — **B. Galileo**
2. **Scientist who introduced laws describing force & motion.** — **C. Newton**
3. **Philosopher who made many discoveries through observation & logical reasoning.** — **A. Aristotle**
4. **A measure of the mass of an object … the tendency to resist change.** — **C. Inertia**
5. **Related to the mass of an object and the acceleration it produces.** — **B. Force**
6. **An objects motion changes (slow down, speed up, direction)** — **A. Acceleration**

Newton’s Second Law of Motion

Math Practice

1. A boy pushes forward a cart of groceries with a total mass of 40.0 kg. What is the acceleration of the cart if the net force on the cart is 60.0 N?

Newton's Second Law of Motion

Math Practice

1. A boy pushes forward a cart of groceries with a total mass of 40.0 kg. What is the acceleration of the cart if the net force on the cart is 60.0 N?

Answer: $a = F/m = 60.0\ \text{N}/40.0\ \text{kg} = 1.50\ \text{m/s}^2$

Newton's Second Law of Motion

Math Practice

2. What is the upward acceleration of a helicopter with a mass of 5000 kg if a force of 10,000 N acts on it in an upward direction?

Newton's Second Law of Motion

Math Practice

2. What is the upward acceleration of a helicopter with a mass of 5000 kg if a force of 10,000 N acts on it in an upward direction?

Answer: $a = F/m$ = 10,000 N/5000 kg = 2 m/s^2

Newton's Second Law of Motion

Math Practice

3. An automobile with a mass of 1200 kg accelerates at a rate of 3.0 m/s^2 in the forward direction. What is the net force acting on the automobile? (*Hint:* Solve the acceleration formula for force.)

Newton's Second Law of Motion

Math Practice

3. An automobile with a mass of 1200 kg accelerates at a rate of 3.0 m/s^2 in the forward direction. What is the net force acting on the automobile? (*Hint:* Solve the acceleration formula for force.)

Answer: $a = F/m$

$$F = m/a = 1200\text{ kg} \times 3.0\text{ m/s}^2 = 3600\text{ N}$$

Newton's Second Law of Motion

Math Practice

4. A 25-N force accelerates a boy in a wheelchair at 0.5 m/s2. What is the mass of the boy and the wheelchair? (*Hint:* Solve Newton's second law for mass.)

Newton's Second Law of Motion

Math Practice

4. A 25-N force accelerates a boy in a wheelchair at 0.5 m/s2. What is the mass of the boy and the wheelchair? (*Hint:* Solve Newton's second law for mass.)

Answer: $a = F/m$

$$m = F/a = 25\ \text{N}/0.50\ \text{m/s}^2 = 50\ \text{kg}$$

Newton's Third Law

states that forces always occur in pairs between two interacting objects. Every action has an equal and opposite reaction.

TRY IT

THINK ABOUT IT

PREDICT

1. Have students stand up next to their desk or table.
2. Push down on your desk real hard (*using your hands "palm down"*) for 10 seconds.
3. Describe the motion of your hands versus the motion of the desk. In other words, what will happen in terms of your hand and the desk?

Newton's Third Law

The desk pushes back up with the SAME amount of force that you push down! … you know this because there is a mark left on your hand

Newton's Third Law

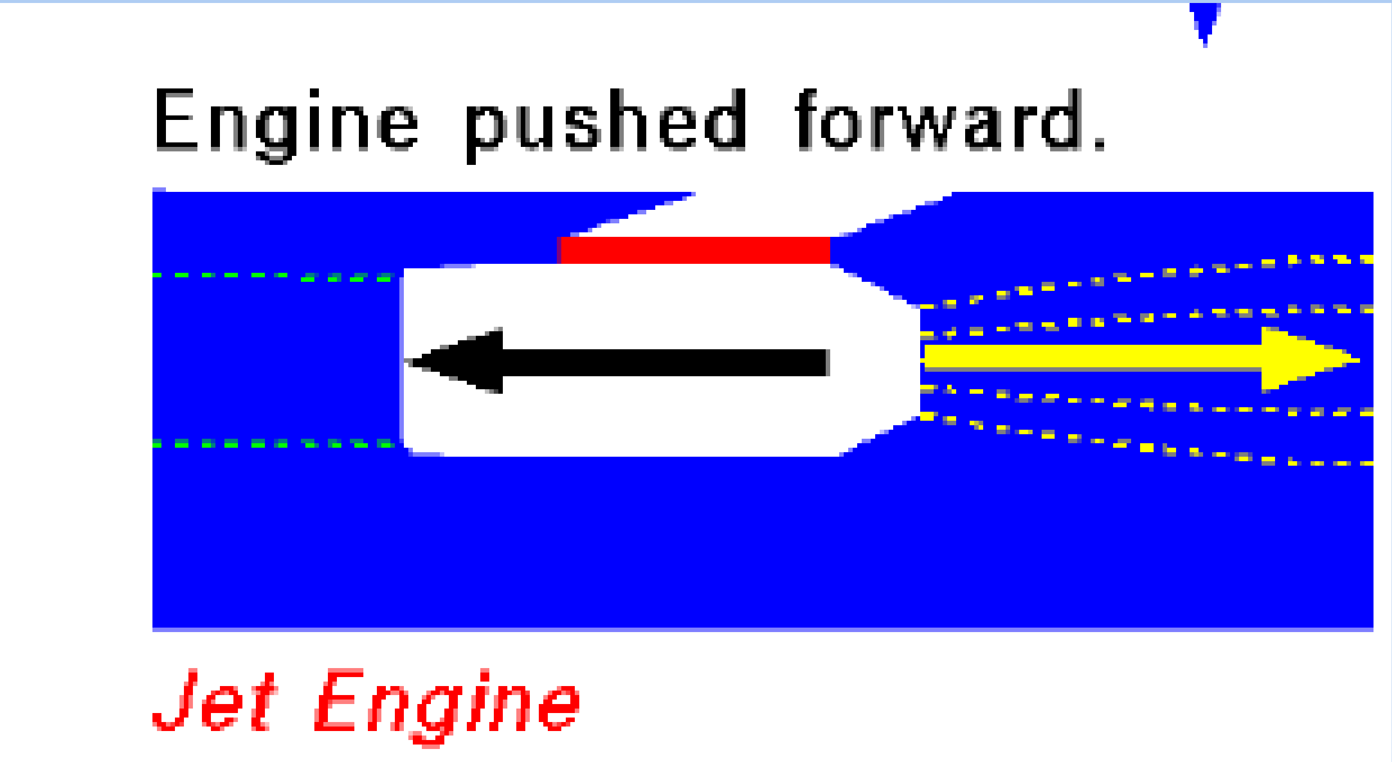
Describe Newton's Third Law for these incredible, but true types of motion.

http://somup.com/cFXQqJniFa
Golf Ball [0:36]

https://screencast-o-matic.com/watch/cFXQqGYSEq
Golf Ball [0:07]

Newton's Third Law

1. A lawn water sprinkler spins around because the force of water pushes in the opposite direction that the sprinkler spins.

2. 

Newton's Third Law

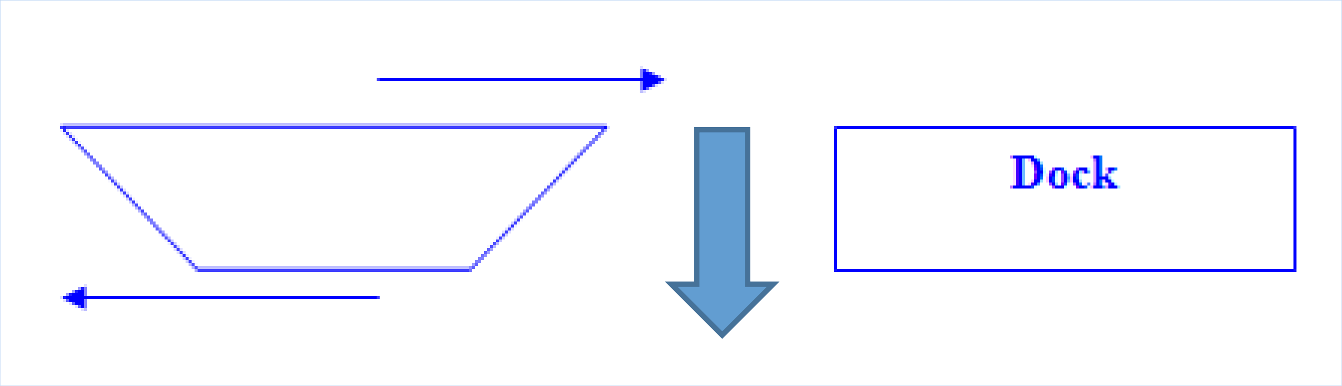
You are in a canoe on a lake **one meter** from the dock. You stand up and take a step to get onto the dock. Will you reach the dock or fall in the water? Make a diagram to explain your answer.

Newton's Third Law

THINK ABOUT IT

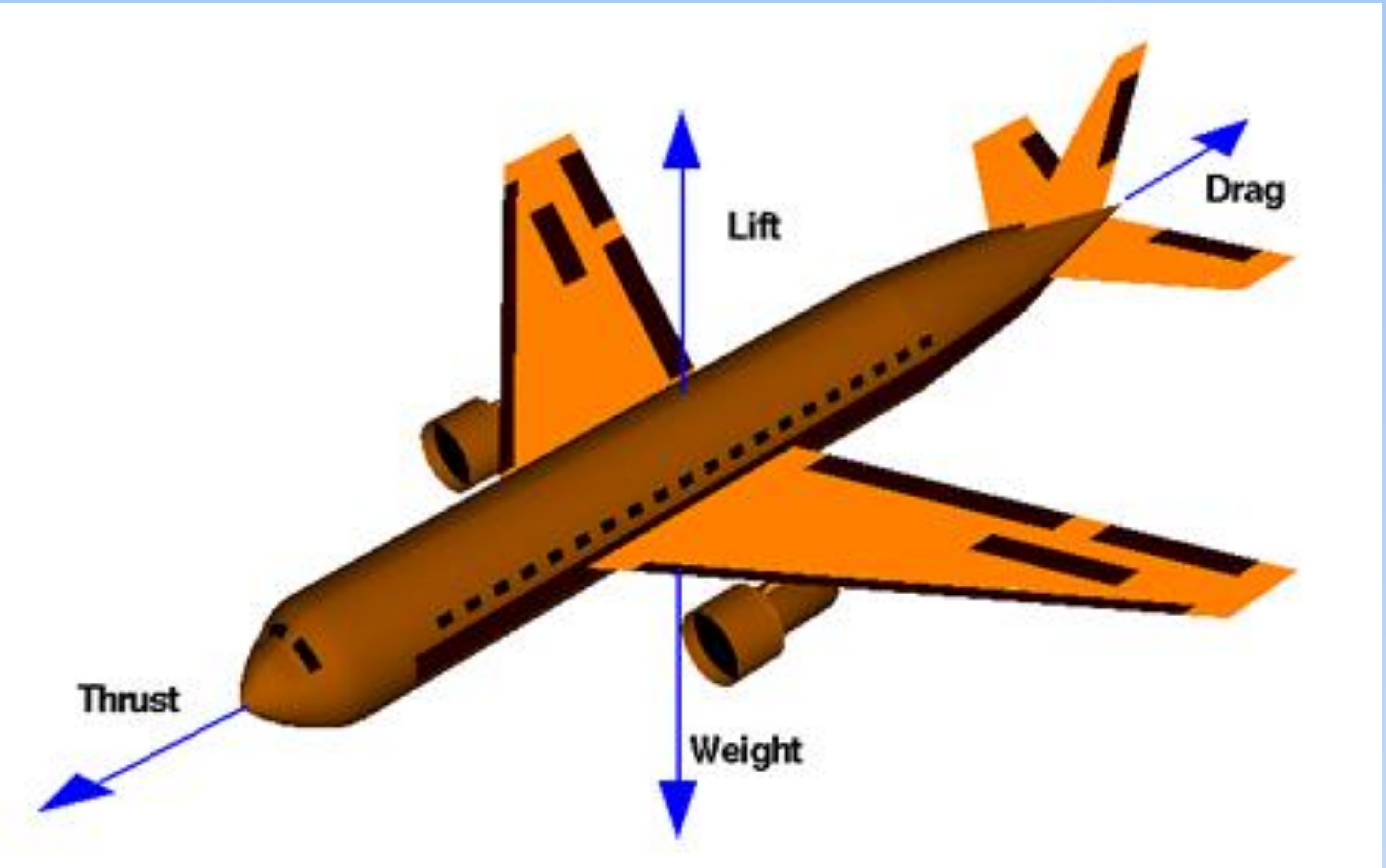
You are in a canoe on a lake one meter from the dock. You stand up and take a step to get onto the dock. Will you reach the dock or fall in the water? Make a diagram to explain your answer.

If one is in a canoe one meter from a dock and tries to take a step to get onto the dock, they would fall into the water. This is because the boat would move away the same amount that one steps towards the dock, leaving only water between the person and the dock.



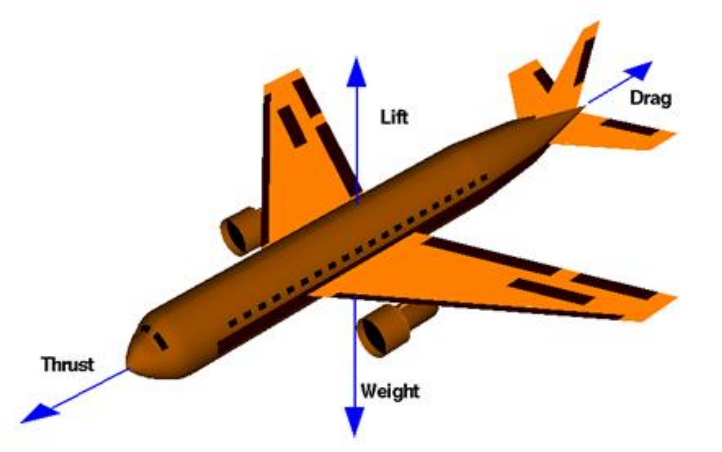
Newton's Third Law

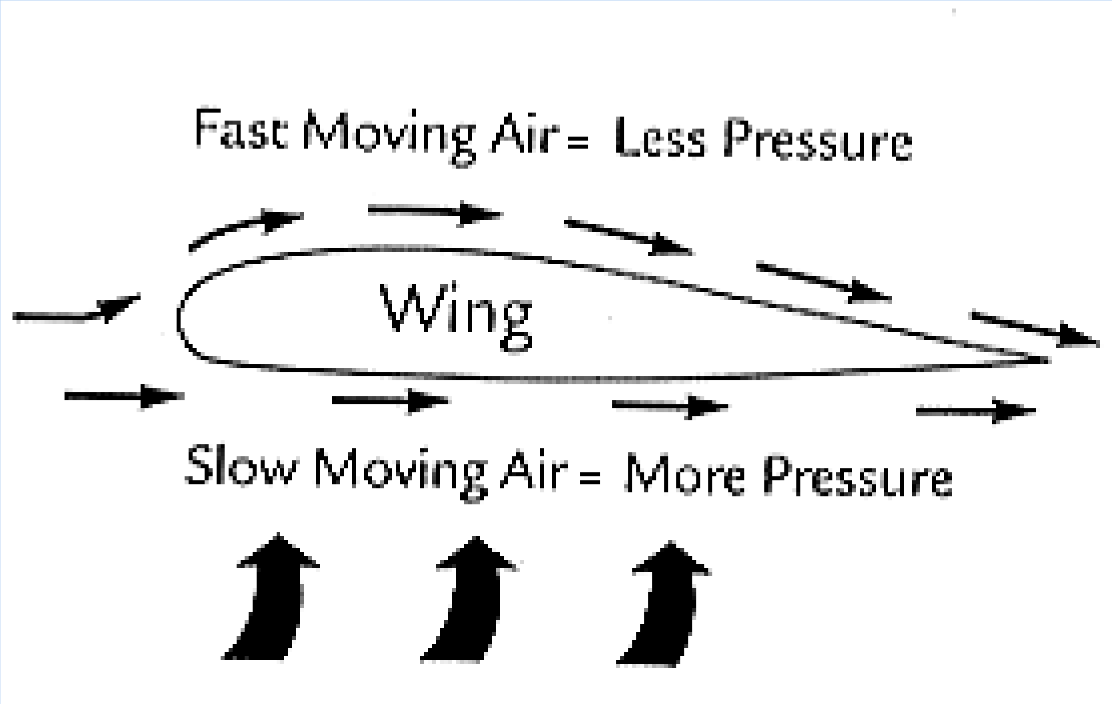
Explain how a jet can fly?



Newton’s Third Law

The jet engine thrusts so air pushes back with equal and opposite force; Then, air flows over the wings and forms a negative pressure above the winds, LIFTING the jet.





Newton's Third Law

Newton's 3rd Law & Momentum (3:58)

Football & Newton's Cradle

http://somup.com/cFXQYeniFH

A. How can a car move on a highway based on Newton’s third law? Does the car or the road move?

B. Why don't you see the road moving away from you when you are in a real car?

C. Would you be able to drive forward if you were not attached to the Earth?

THINK ABOUT IT

A. How can a car move on a highway based on Newton's third law? Does the car or the road move?

The force of the car on the road is equal but in an opposite direction as the force of the road (earth) on the car based on Newton's Third Law.

B. Why don't you see the road (earth) moving away from you when you are in a real car?

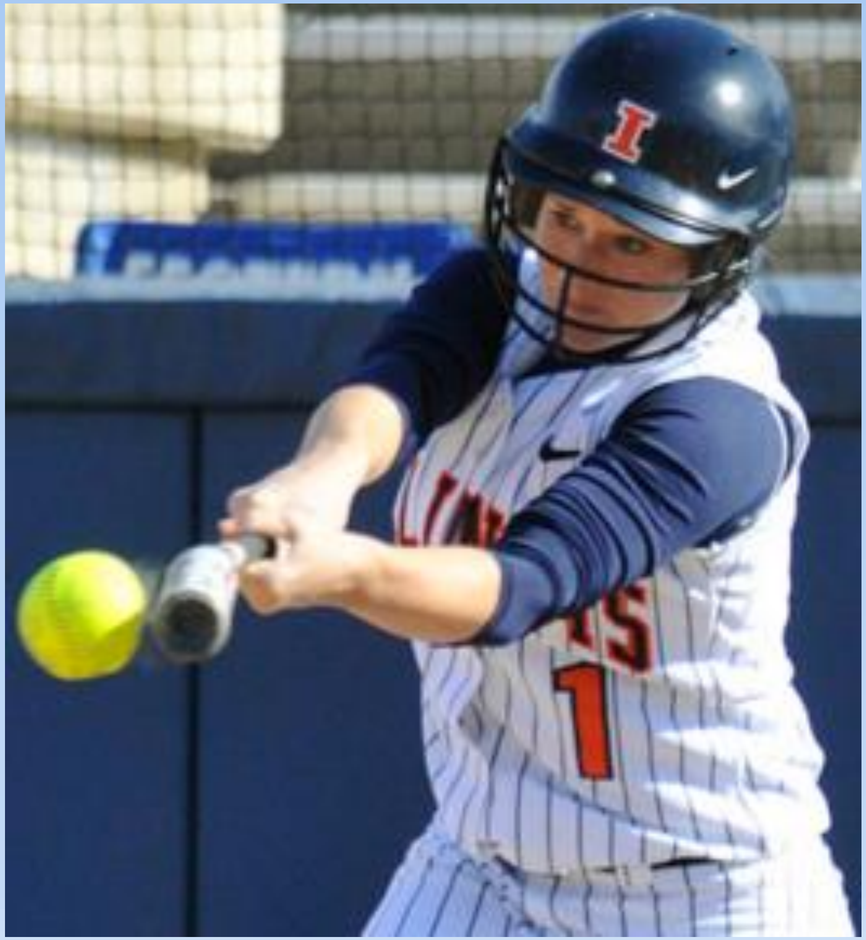
The earth is so much larger than a car but the force on each is equal & opposite. Since f = ma …

$$f_{earth} = ma = f_{car} = ma$$

The forces are EQUAL, but the mass & acceleration are VERY different. This is similar to a bug hitting the windshield of a truck. The force of impact is the same for both the bug and the truck, but the mass and acceleration are VERY different.

C. Would you be able to drive forward if you were not attached to the Earth?

No. You need friction to provide the “opposing” [equal and opposite] force for motion.



Because of Newton’s Third Law, the bat actually bends away and rebounds back. The ball also gets indented on the bat side and rebounds back to its normal shape.

Newton's Third Law Examples

1. Which exerts more force on the other … the earth to the moon or the moon to the earth?
2. Place a rubber band between you thumb and index finger. Which exerts more force on the other … the thumb or the index finger?
3. Which exerts more force on the other … the floor pushing up on you or your weight pushing down on the floor?

QUICK CHECK

Newton’s Third Law Examples

1. Which exerts more force on the other … the earth to the moon or the moon to the earth?

2. Place a rubber band between you thumb and index finger. Which exerts more force on the other … the thumb or the index finger?

3. Which exerts more force on the other … the floor pushing up on you or your weight pushing down on the floor?

According to Newton’s third law, the forces are in pairs. Therefore, all of them are equal and opposite.

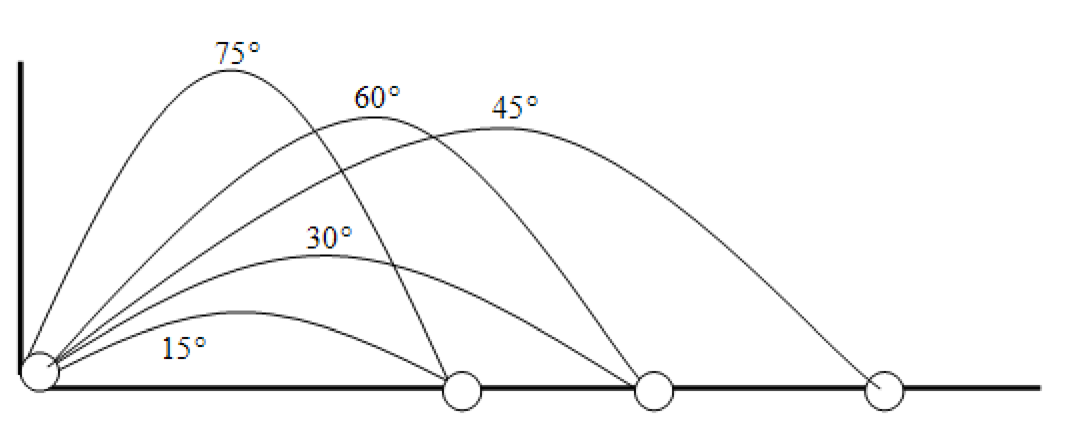
Newton's Laws ctr

http://somup.com/cFXQqpniFy (4:35)

- Fan cart
- Masses hanging on a string
- Balloon
- Minicar
- Bouncy balls

Paper Football

A field goal kicker in football or a soccer player kicks the ball:



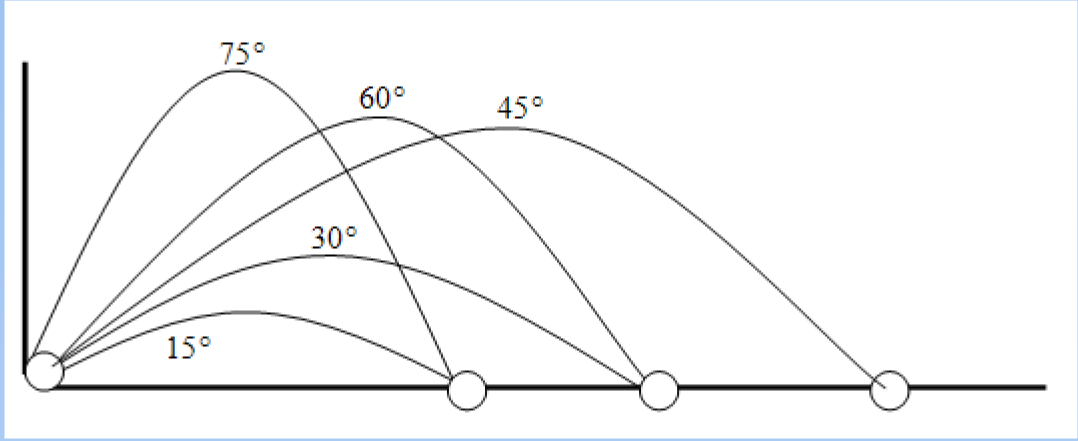
What factors must be considered when kicking the ball?

What aspect is most directly related to how far the ball goes?

How did the kicker decide where to contact the ball?

Would the kicker use the same technique to kick a plastic playground ball?

A field goal kicker in football or a soccer player kicks the ball:



What factors must be considered when kicking the ball? ***Velocity, direction, mass***

What aspect is most directly related to how far the ball goes? ***The greater the force, the farther it goes and the faster it goes [velocity]***

How did the kicker decide where to hit the ball?

It depends on what direction you want it to go and how far you want it to go. The angle and force at which the ball is kicked determines how high and how far it goes.)

Would the kicker use the same technique to kick a plastic playground ball? ***Kicking a heavier object would require more force to get the same results (effects velocity and angle)***

Momentum

- **Inertia** in motion
- Momentum is the product of the mass of an object times its velocity

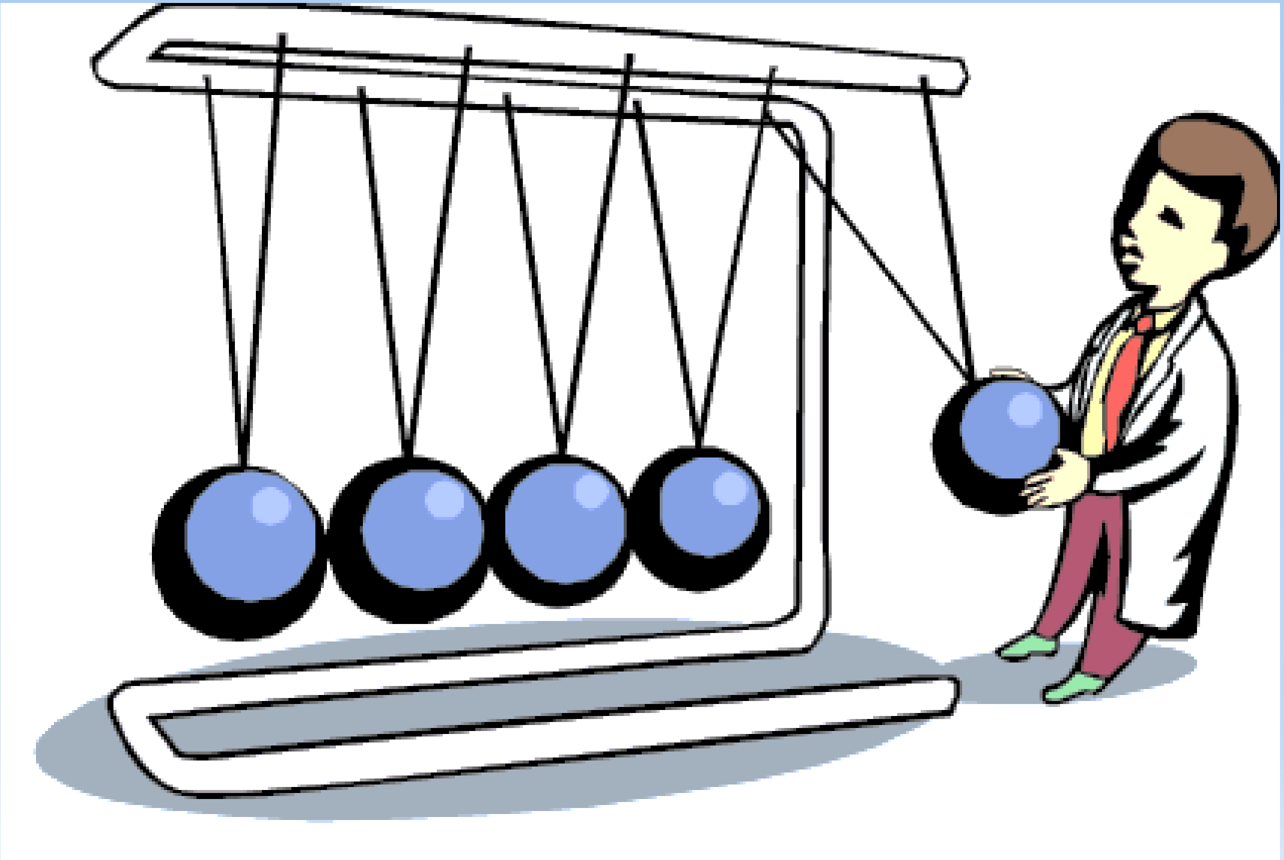
$$\rho = m\,v$$

- Includes mass (m) of objects
- Includes speed (v) of objects
- Includes the angle at which objects collide

Momentum

What happens when the person releases the metal ball into Newton's cradle?

Imagine lining people up shoulder to shoulder and the person shoves the first person in line. Everyone would move to the left.

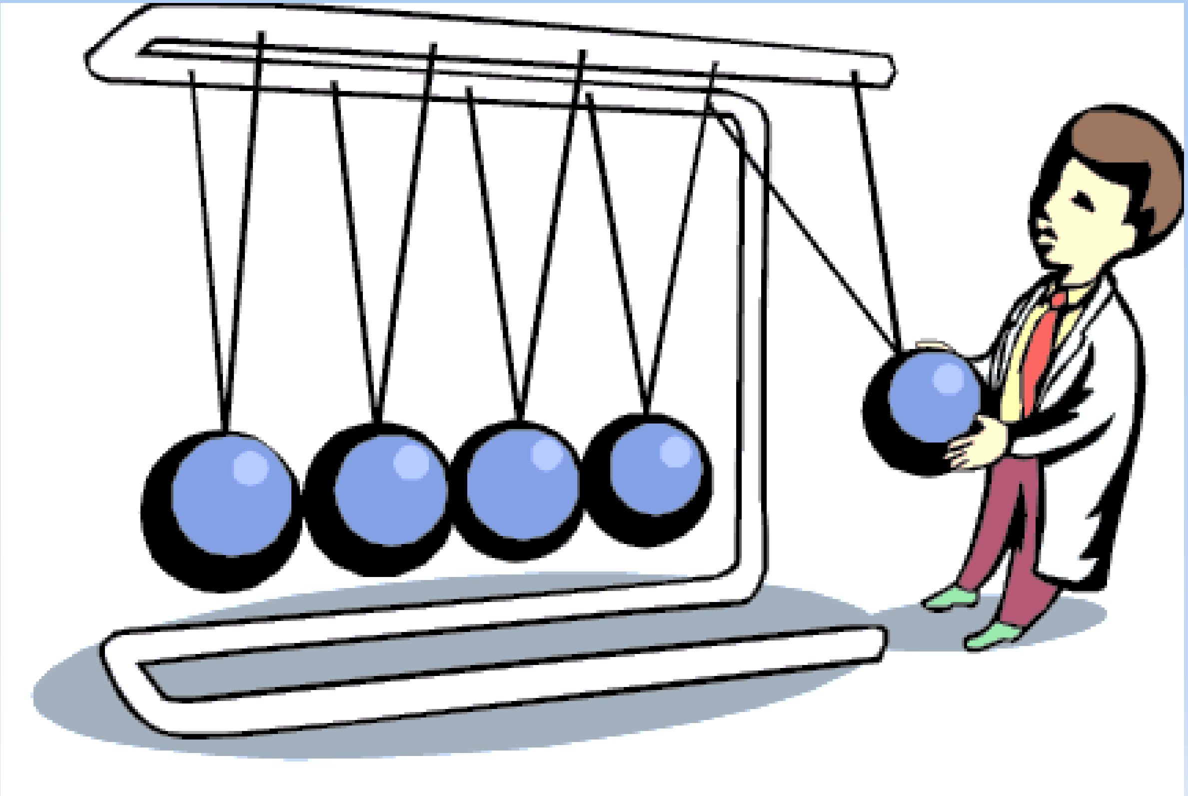


Momentum

ρ = mv … relates to the transfer of motion from one object to another, assume <u>elastic collisions</u> (no heat or KE is lost). (1:42)

http://somup.com/cFXQqRniFE

The metal ball's momentum is transferred from metal ball to metal ball until the ball on the left swings out while the others remain still.



Momentum

QUICK CHECK

Which has greater momentum and why? A skateboard moving 10 mph vs. a parked tractor trailer truck.

Would you rather be hit by a 5 lb weight or a bullet shot out of a gun?

A large super tanker (ship carrying cargo) stops its engines 25 kilometers from port (15.6 miles). How can this be?

Momentum

Which has greater momentum and why? A skateboard moving 10 mph vs. a parked tractor trailer truck. ***for the parked truck: ρ = mv but v = 0; therefore, ρ = 0***

Would you rather be hit by a 5 lb weight or a bullet shot out of a gun? ***It depends on the speed of the objects, but most likely the weight. A bullet has tiny mass, but huge velocity making its momentum larger.***

A large super tanker (ship carrying cargo) stops its engines 25 kilometers from port (15.6 miles). How can this be? ***Momentum, mainly due to the huge mass of the ship, requires about 25 kilometers of water resistance to bring them to a halt.***

$$\rho = m v$$

Newton's Laws & Momentum

Newton's Laws and momentum are some of the most important matters when dealing with sports, engineering, and many other physical objects or activities.

STRATEGY

e.g. Batting

1st law: don't hitch or allow hands to drift when swinging

2nd law: keep ones hands "back" so the bat has more time on the ball

3rd law: the bat bends & recoils, adding force to the ball & the ball indents and recoils off the bat gaining force

mv: the heavier the bat and faster it swings, the faster and farther the ball will travel.

Momentum

Which has more momentum, a 0.046-kilogram golf ball with a speed of 60.0 meters per second, or a 7.0-kilogram bowling ball with a speed of 6.0 meters per second?

Momentum

Which has more momentum, a 0.046-kilogram golf ball with a speed of 60.0 meters per second, or a 7.0-kilogram bowling ball with a speed of 6.0 meters per second?

$$\text{Momentum}_{\text{golf ball}} = 0.046\ \text{kg} \times 60.0\ \text{m/s} = 2.8\ \text{kg}\cdot\text{m/s}$$

Momentum

Which has more momentum, a 0.046-kilogram golf ball with a speed of 60.0 meters per second, or a 7.0-kilogram bowling ball with a speed of 6.0 meters per second?

$\text{Momentum}_{\text{golf ball}} = 0.046 \text{ kg} \times 60.0 \text{ m/s} = 2.8 \text{ kg} \cdot \text{m/s}$

$\text{Momentum}_{\text{bowling ball}} = 7.0 \text{ kg} \times 6.0 \text{ m/s} = 42 \text{ kg} \cdot \text{m/s}$

Momentum

Which has more momentum, a 0.046-kilogram golf ball with a speed of 60.0 meters per second, or a 7.0-kilogram bowling ball with a speed of 6.0 meters per second?

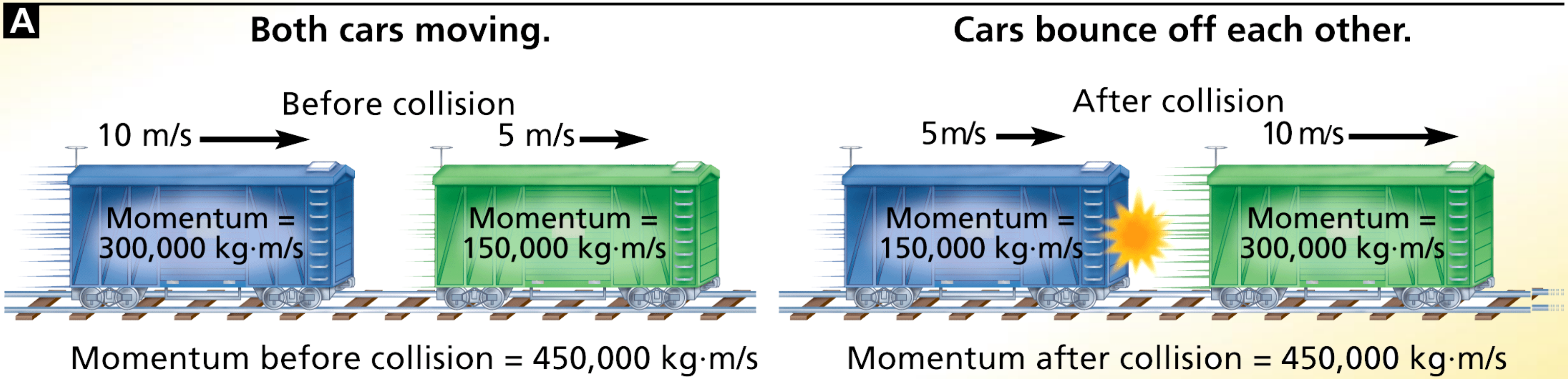
$\text{Momentum}_{\text{golf ball}} = 0.046\ \text{kg} \times 60.0\ \text{m/s} = 2.8\ \text{kg•m/s}$

$\text{Momentum}_{\text{bowling ball}} = 7.0\ \text{kg} \times 6.0\ \text{m/s} = 42\ \text{kg•m/s}$

The bowling ball has considerably more momentum than the golfball.

Conservation of Momentum

In each collision, the total momentum of the train cars does not change—momentum is conserved.



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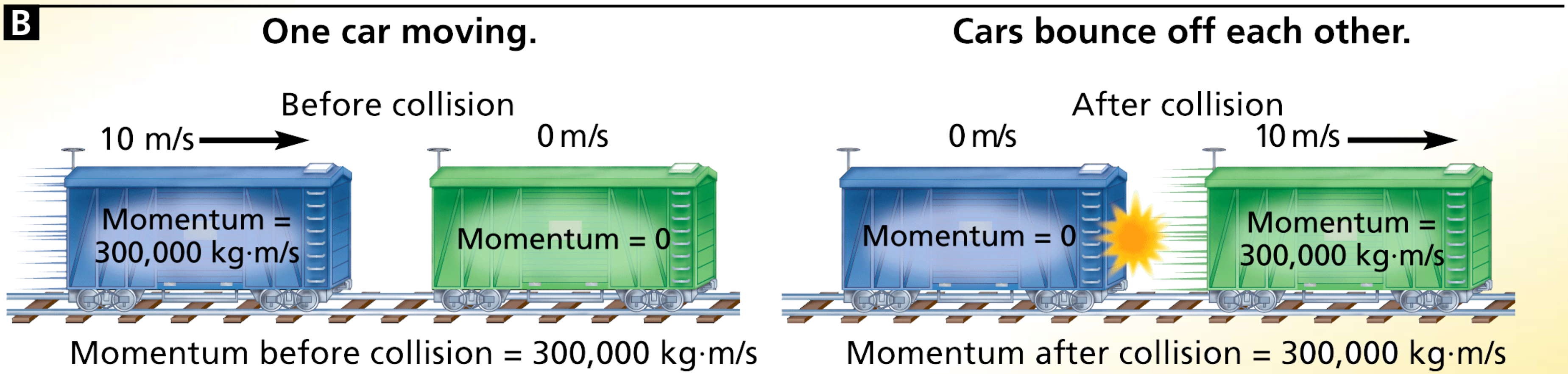

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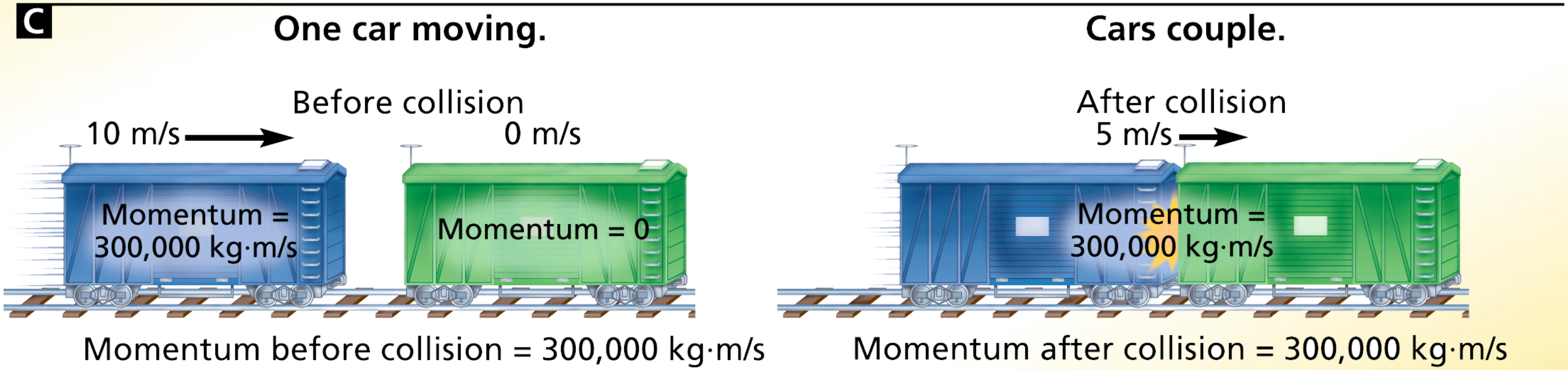
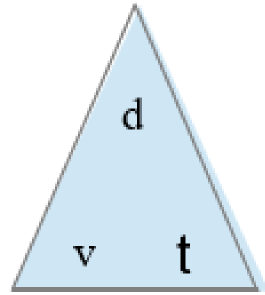


Supplemental Worksheets

- Download the Newton's 2nd Law Worksheet
- Download the Motion Mathematics Worksheet
- Work on problems together (if time)

$s = d / t$

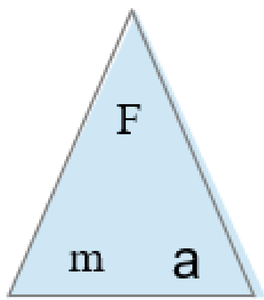
$v = d / t$



$a = \Delta v / t$

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

$F = m\,a$



$d = \frac{1}{2} a t^2$

$v_{instantaneous} = g \cdot t$

Total Energy = PE + KE

$PE = mgh$

$KE = \frac{1}{2} m v^2$

$p = m \cdot v$

$P = W / t$

$V = I \cdot R$