Chapter 10
Forces

Mrs. Valentine

Physical Science

4th and 6th Periods

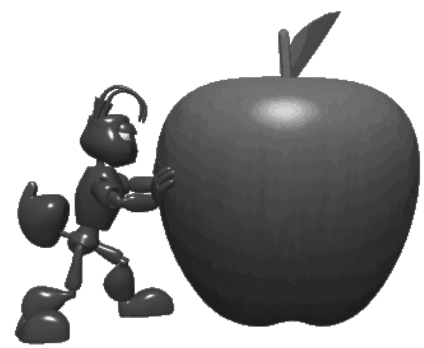
Section 1
The Nature of Force

- Change in motion does not just happen without cause.

- If something is to start or stop moving, it too requires something.

- This something is force.

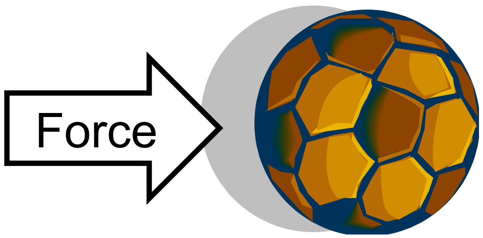
- **Definition:** <u>Force</u> – a push or pull.



Forces

- Like velocity and acceleration, forces are not only described by how strong they are.

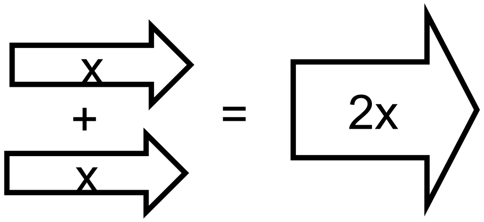
- Forces also have direction.



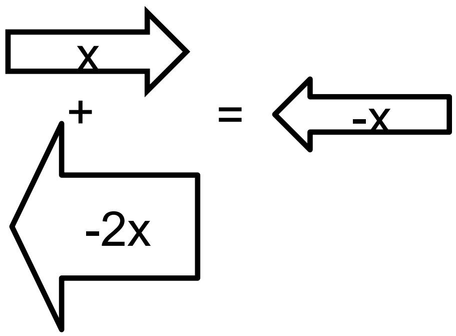
- Gravity, for example, is a force that is acting upon you right now. It is pulling you toward the nearest point on Earth's crust.

- Since force is directional, and can be of different strengths, two forces are not necessarily equal.

Unbalanced Forces

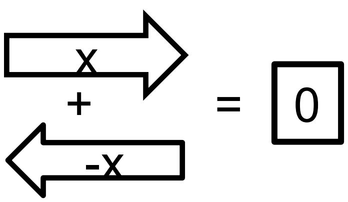


- When two forces are in the same direction, they add together.



- When two forces are in opposing directions, they subtract from each other.

- If one force is bigger than the other, the smaller force cancels out an equivalent portion of the bigger force, leaving some of the bigger force remaining.

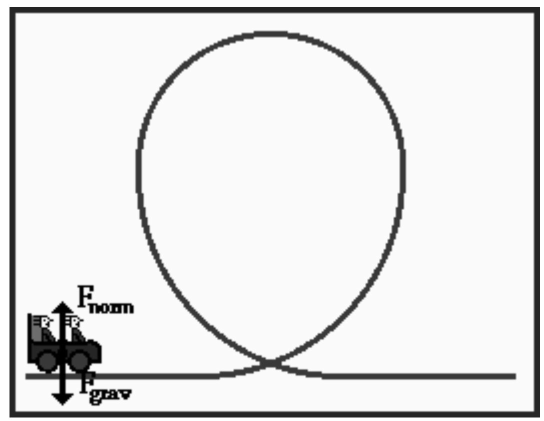


- If the forces are equal and opposite, they are completely cancelled out.

Unbalanced Forces

- **Definition:** Net Force – the overall force on an object after all the forces are added together.

- **Definition:** Unbalanced Force – a nonzero net force that changes an object's motion.

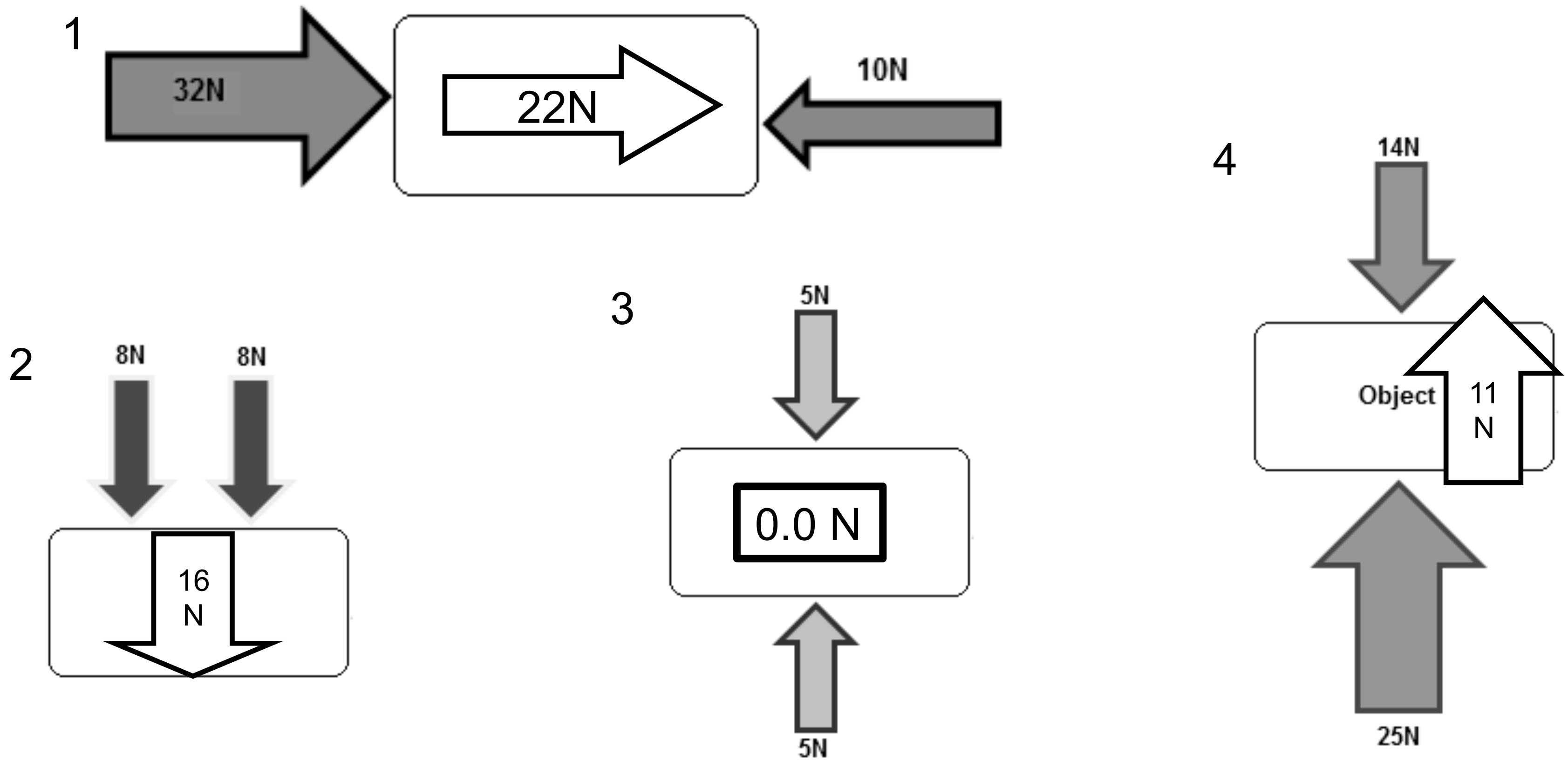


- An unbalanced force will cause an object to accelerate.

- Let's have a look at Exploring Combined Forces on page 315.

Net Force Practice Problems
(p. 6 in packet)

- What is the net force on each of the following objects?



Balanced Forces

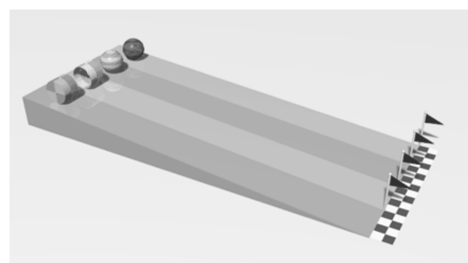
- Exerted forces do not always change the object's motion.

- **Definition:** Balanced Forces – equal forces acting on one object in opposite directions.

- **Balanced forces acting on an object will not change the object's motion.**

Newton's First Law of Motion

- In the early 1600s, Galileo Galilei questioned the idea that a force is needed to keep an object moving.
- He suggested that force is only needed to change the motion of an object.
- **Definition:** Inertia – the tendency of an object to resist change in its motion.



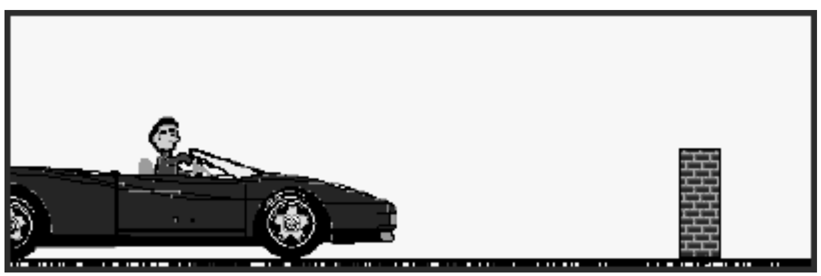
- Sir Isaac Newton discovered the three basic laws of motion in the late 1600s.

Newton's First Law of Motion

- **<u>Newton's first law of motion</u> states that an object at rest will remain at rest and an object that is moving at constant velocity will continue moving at constant velocity unless acted upon by an unbalanced force.**

- This is also called the law of inertia.

- Example – if you are in a car when the brakes are slammed, you continue to move forward.



Demonstration

- *(It’s Not a)* Magic Trick – removing a cloth from under an object without moving the object.
- Materials – several sockets from a wrench set and a cloth.
- Why am I able to move the cloth without hardly disturbing the sockets?
- Answer: The inertia of the sockets kept them in place.

Mass

- Ever notice that it's much more difficult to move a jar of pennies than it is to move a jar of equal volume of cotton?

- The amount of inertia an object has depends on its mass.

- Therefore, <u>mass</u> is also defined as a measure of the inertia of an object.

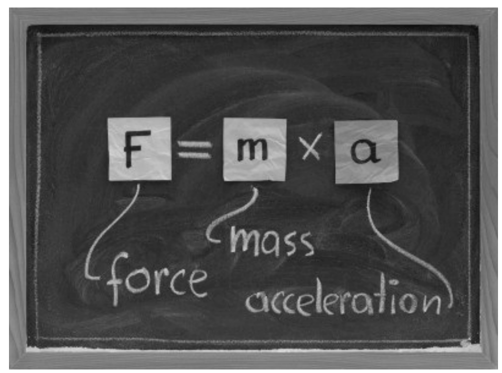
- Recall that the SI unit for mass is the kilogram (kg).

Section 2
Force, Mass, and Acceleration

- Newton's second law of motion explains how force, mass, and acceleration are related.

- **The net force on an object is equal to the product of its acceleration and its mass.**

- The equation for force is:



- This equation itself is often referred to as Newton's second law.

Newton's Second Law of Motion

- Do not forget to pay attention to the units of measurement.

- When acceleration is measured in m/s^2 and mass is measured in kg, force is measured in kilograms * meters per second per second.

- **Definition:** Newton – one Newton equals the force required to accelerate one kilogram of mass at 1 meter per second per second.

$$1N = 1kg*1m/s/s = 1kg*1m/s^2$$

Force Practice Problems (p. 6 in packet)

$F = m*\alpha$

- If a **25kg** wagon is being pulled at an acceleration of **2.5m/s²**, what is the force on the wagon?

$m = 25kg$

$\alpha = 2.5m/s^2$

$F = (25kg)*(2.5m/s^2)$

$F = 62.5kg*m/s^2 = 62.5N$

- If a 45kg boy was added to the same wagon, and the force was not changed, what is the new acceleration of the wagon?

$\alpha = 0.89\ m/s^2$

Changes in Force and Mass

- Let's have a look at Figure 6 on page 322.
- How can you increase the acceleration of this wagon?
- Answers: Increase the force or decrease the mass.
- How would we do these things?
- Answer, pull it harder (or downhill), or remove one of the boys from the wagon.

Section 3
Friction and Gravity

- If you push a book across a desk, will the book continue to move when you let go? Why or why not?

It will not. Friction prevents the book from continuing.

- If you pick up a book, will it stay put when you let it go, or will it fall? Why?

Gravity will pull the book back toward the desk.

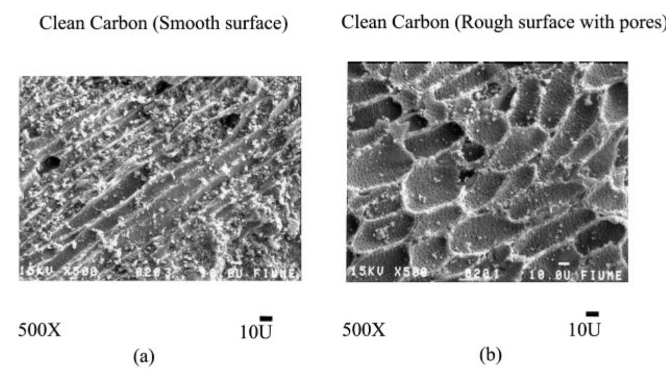
- From Newton's first law, we know that in each case, an unbalanced force must be acting on the book.

- There are two forces at work here: friction and gravity.

Friction

- Pushing the book across the table, the surface of the book rubs against the surface of the table.

- Although some surfaces seem smooth, they can actually be quite rough (see figure 7 on page 324).



- When the two surfaces rub against one another, irregularities get caught.

- **Definition:** <u>Friction</u> – the force that one surface exerts on another when the two rub against each other.

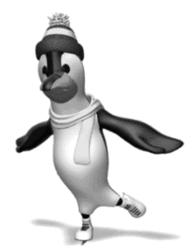
The Nature of Friction

- Friction acts in the opposite direction of the movement of an object.

- Without friction, the book would continue across the desk until another force stopped it.

- **The strength of the force of friction depends on two factors: the types of surfaces involved and how hard the surfaces push together.**

- Compare the friction between a runner and the pavement to an ice skater and the ice.



Is Friction Useful or Not?

- To answer this, let's watch the Magic School Bus: Plays Ball.

- So what can we say about the usefulness of friction?
  - Walking
  - Playing sports
  - Lighting a Match
  - Slowing down when going too fast
  - Ballerinas use a sticky powder to prevent themselves from slipping




Controlling Friction

- In order to control friction, you must understand about the different kinds of friction.

- **Definition:** <u>Sliding Friction</u> – resistance when solid surfaces slide over each other.

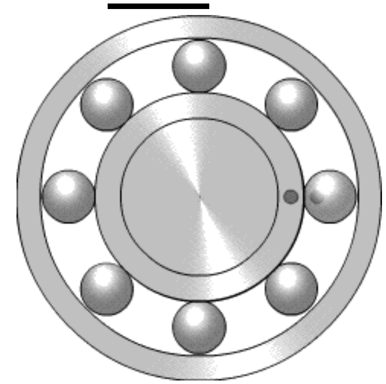
- **Definition:** <u>Rolling Friction</u> – resistance when an object rolls over a surface.

- **Definition:** <u>Fluid Friction</u> – resistance due to an object moving through fluid.

Controlling Friction

- The force needed to overcome rolling friction is much less than the force needed to overcome sliding friction.

- One way to overcome some of the friction is to use ball bearings, which are small smooth steel balls.



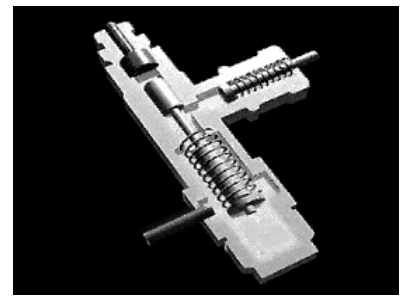
- Ball bearings roll between moving metal parts.

- Several devices use these, including skates, bikes, and even cars.

Controlling Friction

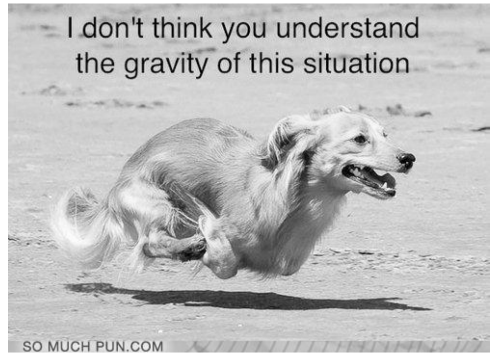
- The force needed to overcome fluid friction is usually less than that needed to overcome sliding friction.

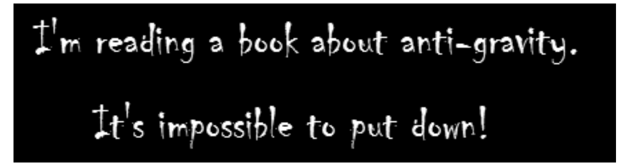
- Fluid usually prevents two surfaces from making direct contact, thus reducing friction.



- Lubricants, such as car oil, are used in this case. Other examples include:

Gravity

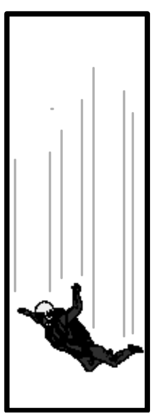




- **Definition:** Gravity – the force that pulls objects towards Earth.

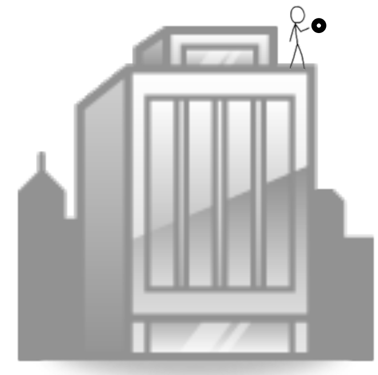
- When sitting under and apple tree, an apple fell on Newton's head. He began to wonder why.

- **Definition:** Free Fall – when the only force acting on a falling object is gravity.

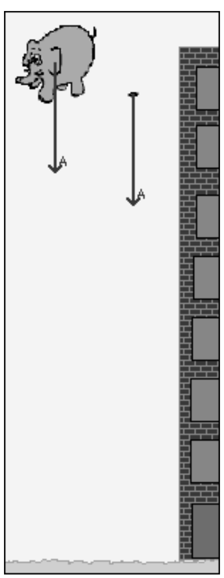


  - In free fall, the force of gravity is unbalanced. Therefore, objects in free fall are accelerating.

Free Fall



- An object in free fall accelerates at $9.8 m/s^2$.
- Let's suppose that we drop an object off a building, starting at 0m/s.
- After the first second, the object is traveling at 9.8m/s.



- After two seconds, the object is traveling at 19.6m/s.
  (9.8m/s + 9.8m/s)
- All objects in free fall accelerate at the same rate, regardless of mass.

Projectile Motion

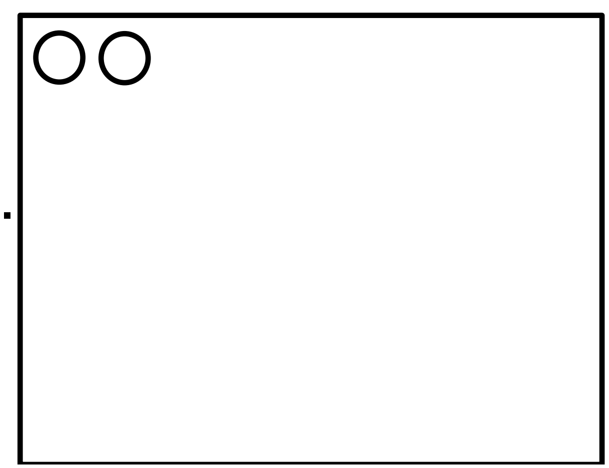
- What happens if an object is thrown instead of dropped?

- **Definition:** Projectile – an object that is thrown.

- An object that is dropped and an object thrown horizontally are both in free fall.

- The horizontal motion of the projectile does not interfere with its free fall.

- Both will hit the ground at the same time. See Figure 11 on page 326.

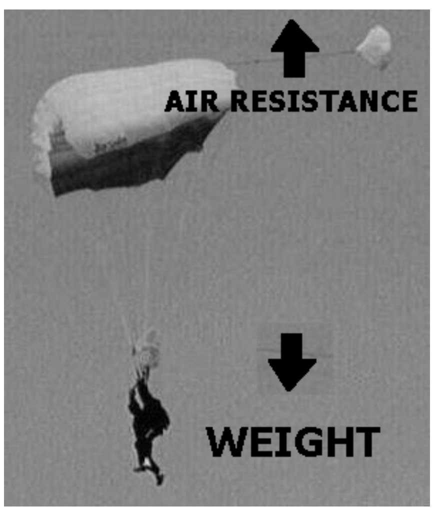


Air Resistance

- Even though all objects are supposed to fall at the same rate, they do not.

- Why is this?

- **Definition:** Air Resistance – the fluid friction experienced by objects falling through the air.

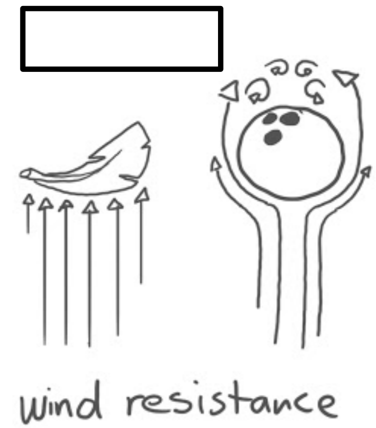


- Reminder: Friction is in the opposite direction of motion.

- Air resistance is therefore in the opposite direction of the motion.

Air Resistance

- Air resistance is not the same for all objects.



- The greater the surface area of an object, the greater the air resistance.
- Air resistance increases with velocity.
- Therefore, air resistance increases the longer an object is in free fall.
- In a vacuum with no air, all objects fall with the same rate of acceleration. See Figure 12 on page 327.

Air Resistance

- Eventually, the air resistance will equal the force of gravity.
- What do you think happens at this point?
- When forces are balanced, there is no acceleration.
- **Definition:** Terminal Velocity – the greatest velocity the object reaches in free fall.

Weight

- **Weight is a measure of the force of gravity on an object, and mass is a measure of the amount of matter in that object.**

- Since weight is a force, you can rewrite Newton's second law to find weight.

$$F = m * \alpha$$

$$Wt = m * \alpha_{gravity}$$

Universal Gravitation

- Planets are not the only objects to exert a gravitational force.
- Newton discovered the law of universal gravitation.
- **The law of universal gravitation states that the force of gravity acts between all objects in the universe.**
- Another way to say this would be to say that each object exerts a force of gravity on every other object in the universe.

Universal Gravitation

- The strength of these gravitational forces are dependant on the masses of the objects exerting them.

- Your weight on the moon is smaller than that on Earth. This is because the moon's gravitational pull is less due to it having less mass.

- Why don't we feel the gravitational force from the sun or the moon while on Earth?

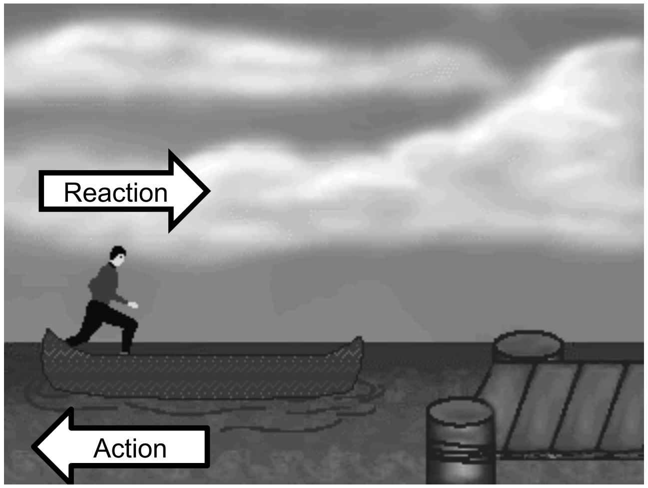
- Gravitation depends on distance.

Section 4
Action and Reaction

- Forces are not “one-sided.”

- **Newton’s third law of motion states that if one object exerts a force on another object, then the second object exerts a force of equal strength in the opposite direction on the first object.**

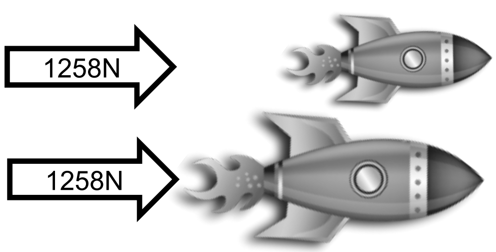
- A good example of this law is a man jumping out of a boat.



Equal but Opposite

- The acceleration of the two objects pushing on one another depends on their mass.

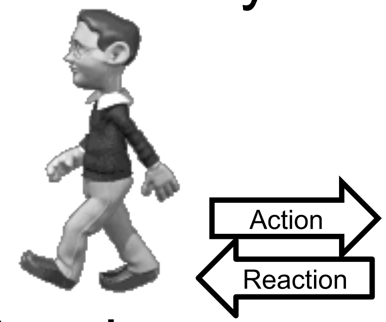
- Therefore, even if the same force is put on both objects in opposite directions, one may accelerate more than the other.



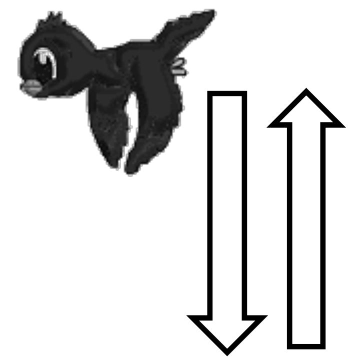
- This is Newton's second law of motion in action.

Action-Reaction in Action

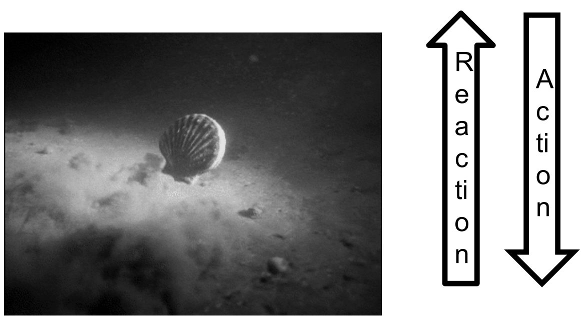
- When you are walking, the ground is pushing back at you.



- This is what enables you to go forward.
- When a bird flies, the air is pushing back on its wings, enabling it to stay in the air.



- Let's look at Figure 17 on page 333.



- Many sea creatures, including scallop, use this kind of jet propulsion to move around in the water.

Do Action-Reaction Forces Cancel?

- If balanced forces cancel, and every force has an equal and opposite force, how is motion possible?
- It is possible because the equal and opposite force caused by another force is most likely on a different object.
- Let's look at Figure 18 on page 334.

Force A is acting on the box while force B is acting on the girl.

- Forces can only be added together if they are acting on the same object.

Momentum

- **Definition:** <u>Momentum (ρ)</u> – the “quantity of motion” defined as the product of an object’s mass and velocity.

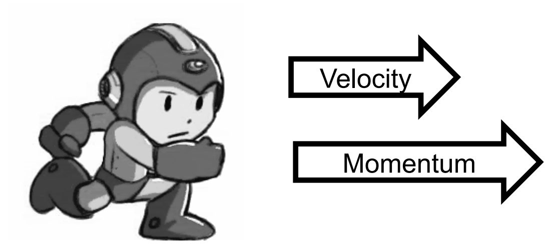
$$\rho = m * v$$

- What do you think the SI unit of momentum is?

kg*m/s

- Since momentum is based upon velocity, not speed, it too has a direction.

- The direction of the momentum is the same as the direction of an object’s velocity.



Momentum

- The more momentum an object has, the harder it is to stop.

- Imagine a ball and a car. Both are moving at 20m/s. Which is easier to catch? Why?

Greater Momentum

- The greater the mass, the greater the momentum.

- High velocity can also produce a large momentum, even with a small mass.

Conservation of Momentum

- Momentum is useful in determining what will happen when two objects collide.

- **Definition:** The Law of Conservation of Momentum – the total momentum of objects in an interaction does not change.

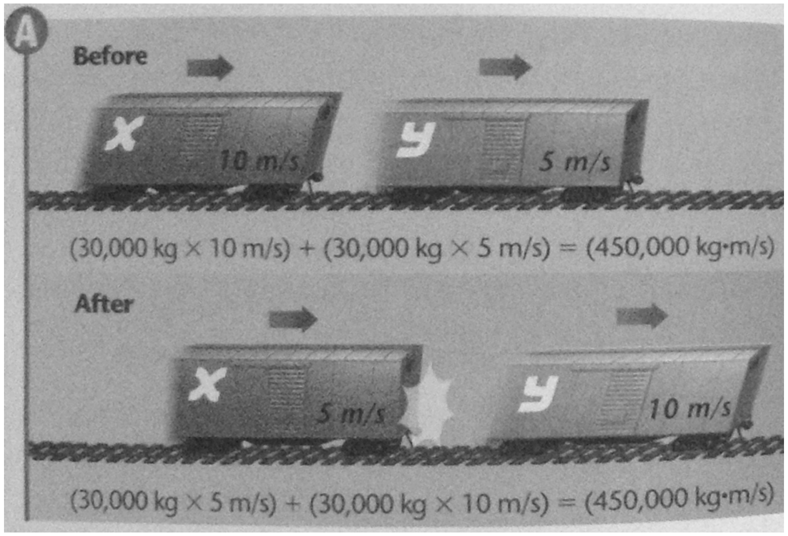
- **The total momentum of any group of objects remains the same unless outside forces act on the object.**

$$\rho_1 + \rho_2 + \ldots + \rho_n = \rho_T$$

- Some of the individual momentums may change, but ρ_T will remain the same.

Conservation of Momentum

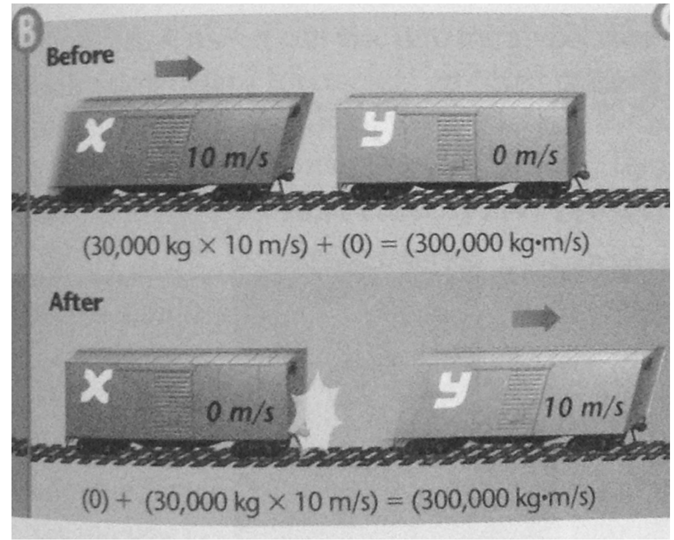
- In physical science, conservation refers to conditions before and after an event.
- A quantity is conserved if it is the same both before and after an event.
- Let's look at Figure 19 on page 336. Assume Cars X and Y have the same mass.



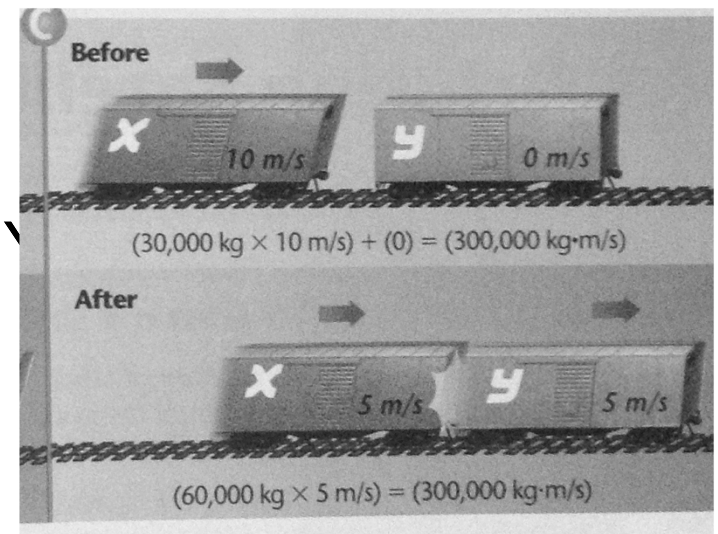
- Figure 19A – two cars are travelling in the same direction. Car X is moving faster than Car Y, but is behind Car Y. They collide. Car X slows and Car Y speeds up by the same amount. The total momentum is the same.

Conservation of Momentum

- Figure 19B – Car X is moving and Car Y is not moving, but Car X is behind Car Y. They collide. Car X stops and Car Y begins to move at the same velocity Car X had been moving at. The total momentum is the same.



- Figure 19C – Car X is moving and Car Y is not moving, but Car X is behind Car Y. Car X connects to Car
causing Car X to slow down and Car Y to speed up. The total momentum is the same.



Momentum Practice Problems (p. 7 in packet)

- If Jenny has a mass of **40kg** and is moving at **10m/s**, what is Jenny's momentum?

  m = 40kg

  v = 10m/s

  ρ = (40kg)*(10m/s)

  ρ = 400kg*m/s

- If Susan has a momentum of 530kg*m/s and has a mass of 51kg, what is Susan's velocity?

  v = 10.4m/s

- If Anakah has a momentum of 450kg*m/s and is moving at 15m/s, what is Anakah's mass?

  m = 30kg

More Momentum Practice Problems (p. 7 in packet)

- Amy and Lenny are ice skating. Lenny has a mass of **95.25kg** and is moving at a velocity of **6.5m/s** eastward. Amy has a mass of **129.3kg**, is behind Lenny, and is moving at a velocity of 9.4m/s eastward. They collide, but do not stick together. Lenny's new velocity after the collision is **7.2m/s** eastward. What is **Amy's new velocity**?

m_L = 95.25kg
v_{Li} = 6.5m/s
v_{Lf} = 7.2m/s

m_A = 129.3kg
v_{Ai} = 9.4m/s
v_{Af} = ?

Practice Problem Solution

- According to the Law of Conservation of Momentum, the total initial momentum must equal the total final momentum.

- Therefore,

$$\rho_{Li} + \rho_{Ai} = \rho_{Lf} + \rho_{Af}$$

- Using the information pulled from the problem, we can solve for Lenny’s initial momentum, Lenny’s final momentum, and Amy’s’ initial momentum.

Practice Problem Solution

- There are five steps to solving a problem like the one on the previous slide:
  1. Find both initial momentums.
  2. Add both initial momentums together to find total momentum.
  3. Find person 1's final momentum.
  4. Subtract person 1's final momentum from the total momentum to find person 2's final momentum.
  5. Divide the difference by person 2's mass to find person 2's final velocity.

Practice Problem Solution

$\rho = m^*v$ and $\rho_{Li} + \rho_{Ai} = \rho_{Lf} + \rho_{Af}$

ρ_{Li} = (95.25kg)(6.5m/s) = 619.125kgm/s

ρ_{Ai} = (129.3kg)(9.4m/s) = 1215.42kgm/s

ρ_{Lf} =(95.25kg)(7.2m/s) = 685.8kgm/s

619.125kgm/s + 1215.42kgm/s = 685.8kgm/s + ρ_{Af}

1834.545kgm/s = 685.8kgm/s + ρ_{Af}

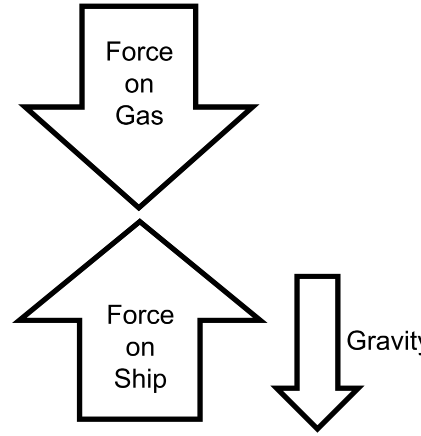
ρ_{Af} = 1834.545 – 685.8 = 1148.745kgm/s

(129.3kg)(v_{Af}) = 1148.745kgm/s

(1148.745kgm/s)/(129.3kg) = v_{Af}

8.88m/s eastward = v_{Af}

Section 5
Orbiting Satellites



- How do rockets lift off?

- As rocket fuel burns, it expels exhaust gases. These gases provide a force against the ground.

- **A rocket can rise into the air because the gases it expels with a downward force exert an equal but opposite force on the rocket.**

- This force is greater than that of gravity.

What is a Satellite?

- **Definition:** Satellite – any object that travels around another object in space.

- An artificial satellite is a device launched into Earth's orbit for one of a variety of purposes.

- What are some purposes of artificial satellites?
    - Space research
    - Communications
    - Weather analysis
    - Military intelligence
    - Geographical surveys

Circular Motion

- Reminder: objects in circular motion are constantly accelerating.

- If an object is constantly accelerating, there must be an unbalanced force acting upon it.

- **Definition:** <u>Centripetal force</u> – any force that causes an object to move in a circle.

Satellite Motion

- If a satellite is circling the Earth, what is the centripetal force acting upon it?
- If gravity is acting upon the satellite, why doesn’t it fall back to Earth?
- Isaac Newton wondered what would happen if you were on a high mountain and were able to throw a stone as fast as you wanted. See Figure 23 on page 340.
- At some point, you would be able to throw the stone at a velocity where the stone’s curve matched that of the Earth.

Satellite Motion

- This stone would be falling toward Earth, but since the Earth is rotating, it would seem to be circling Earth.

- **Satellites orbit around Earth continually fall toward Earth, but because Earth is curved they travel around it.**

- Satellites fall *around* Earth instead of towards it.

- Why don’t satellites need fuel?

Satellite Location

- Lets read the last paragraph on page 340.

Chapter 10 Review:

Answer questions 1-10, 15-17, 21-24

On pages 342-343

Frank, D. V., Little, J. G., Miller, S., Pasachoff, J. M., & Wainwright, C. L. (2001). *Physical science*. Needham, Mass.: Prentice Hall.