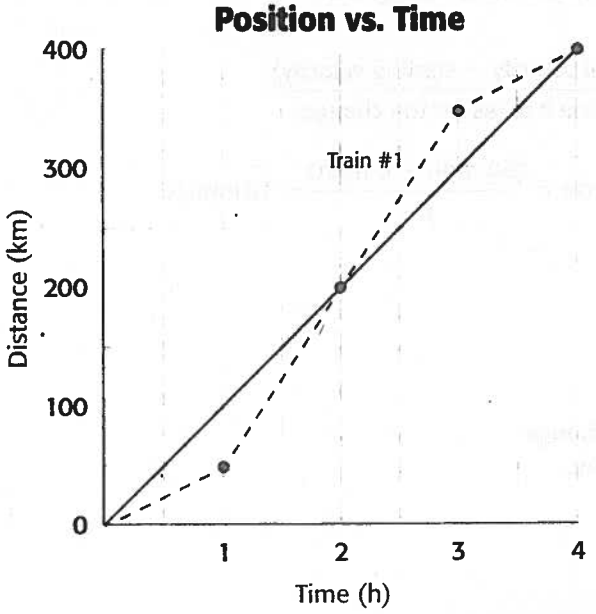
LESSON

83

Speed

How do you calculate speed?

Speed is the rate at which an object moves. Another way to define speed is as a change in position over time. To determine speed, you need to know the distance an object traveled and the time it took to get there. The graph below shows the change in position of a train over the course of 4 hours.



The dotted line on the graph shows that a train traveled different distances in different hours: 50 km in the first hour, 150 km in the second, 150 km in the third, and 50 km in the fourth. The solid line shows the average distance traveled in 4 hours. You can calculate the average speed of the train using this equation:

$$\text{Average speed} = \frac{\text{total distance traveled}}{\text{total time of travel}}$$

$$\text{Average speed of the train} = \frac{400 \text{ km}}{4.0 \text{ h}} = 100 \text{ km/h}$$

Note that the slope of the line on the graph indicates the train's speed. A faster train would have a steeper slope. A slower train would have a less-steep slope.

Show What You Know

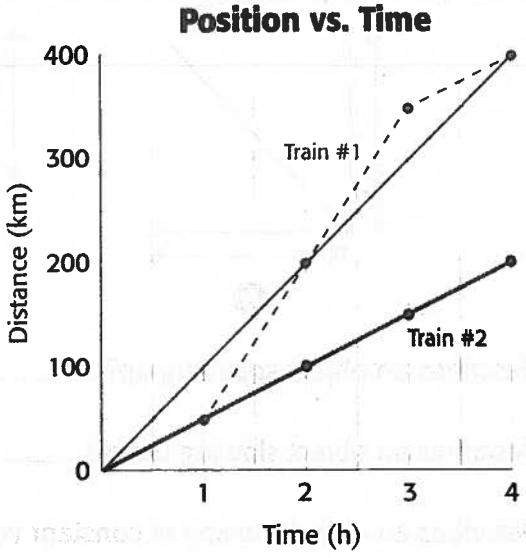
1. Use the graph to determine the average speed of Train #2. Don't forget to include units in your answer.

_____

2. How can you tell that Train #1 is traveling faster than Train #2 just by looking at the graph?

_____

_____



LESSON 84

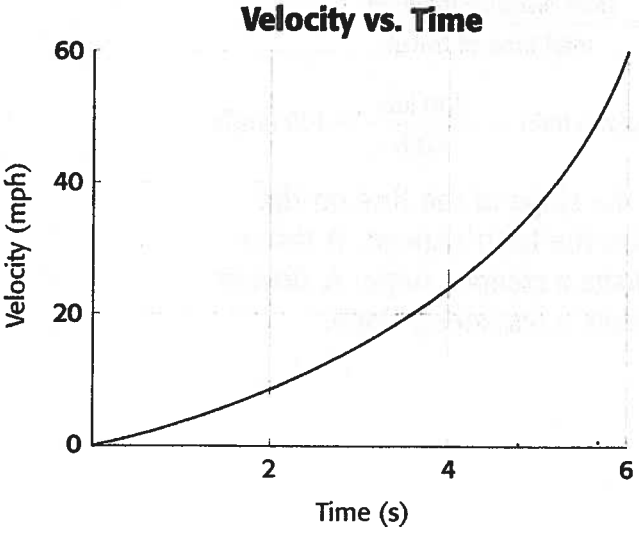
Velocity and Acceleration

What are velocity and acceleration?

Velocity is the speed of an object *in a particular direction*. Let's say two cars travel at the same speed but in different directions. Although the cars have the same speed, they do not have the same velocity. That's because they are moving in different directions.

The velocity of a moving object changes if either its speed or its direction of travel changes. **Acceleration** is the rate of change of velocity. Acceleration can mean speeding up or slowing down. Slowing down is sometimes called deceleration. Acceleration can also mean a change in direction.

The graph shows the velocity of a car as it accelerates to 60 mph in 6 seconds. Acceleration is calculated using this equation:



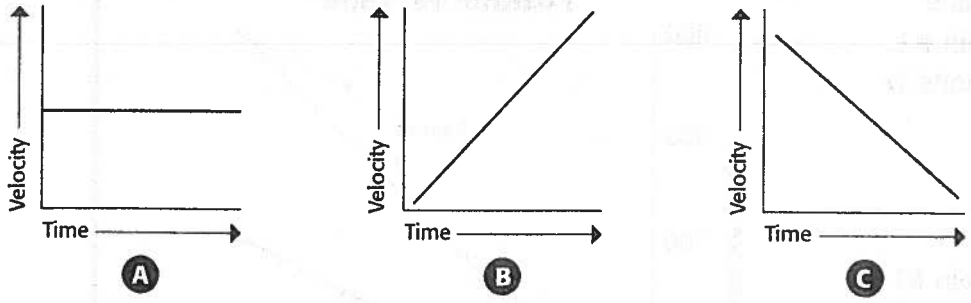
$$\text{Acceleration} = \frac{(\text{final velocity} - \text{starting velocity})}{(\text{time it takes for the change})}$$

$$\text{Acceleration of the car} = \frac{(60\ \text{mph} - 0\ \text{mph})}{6\ \text{s}} = 10\ \text{mph/s}$$

Acceleration is a change in velocity over time.

Show What You Know

Use the graphs to answer the questions.



1. Which graph describes an object speeding up? _____

2. Which graph describes an object slowing down? _____

3. Which graph describes an object moving at constant velocity? _____

LESSON 85

Friction

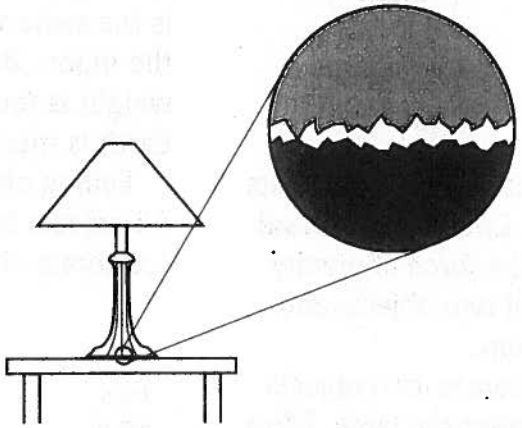
What causes friction?

A **force** is a push or a pull on an object. A force may cause the object to start moving, stop moving, or change direction. Force is measured in **newtons (N)**.

If you try to push a heavy crate across a floor, the force you exert may not be enough to move the crate. Friction makes the crate hard to move. **Friction** is a force that opposes the motion of two surfaces that are touching. The amount of friction depends two things—the size of the force pressing the surfaces together and the roughness of the surfaces.

Imagine pushing an object across a floor. Pushing creates **sliding friction** that works in the direction opposite your push. Now imagine putting rolling wheels on the object. Only the surfaces of the wheels are in contact with the floor. Less surface contact means less friction, so **rolling friction** is less than sliding friction.

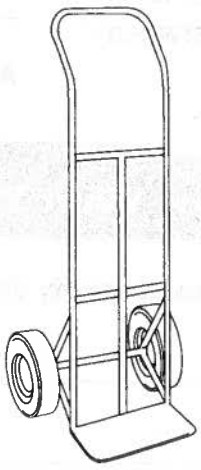
Lubricants help reduce friction between objects. Motor oil is a lubricant used to prevent moving parts in a car's engine from wearing down. Sometimes, friction can be helpful. Sand is often used on icy walkways to increase friction between the ground and a walker's shoes.



Even surfaces that appear smooth are rough if examined close-up.

Show What You Know

A "dolly" is a cart used to move heavy boxes and pieces of furniture. Explain why it takes less force to move heavy objects using a dolly than simply pushing them along the ground.

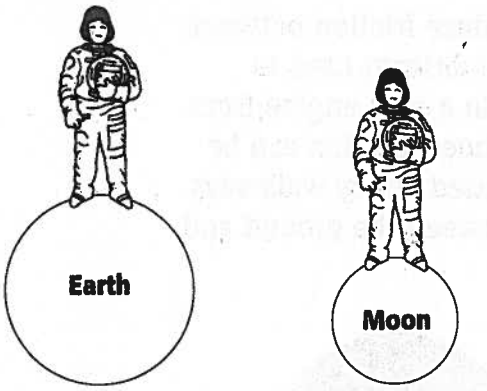


LESSON

86

Gravity

Why do objects fall?



Mass = 60 kg
Weight = 588 N

Mass = 60 kg
Weight = 98 N

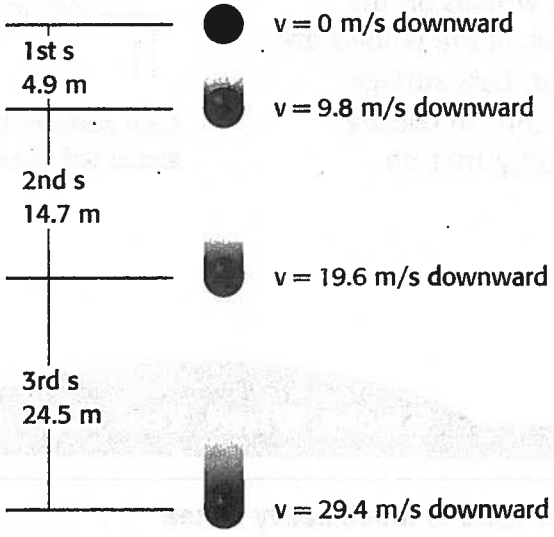
Gravity is a force of attraction that exists between all objects. The **Law of Universal Gravitation** states that the force of gravity depends on the masses of two objects and the distance between them.

Gravitational force between two objects is greater when their masses are large. Most objects have too little mass to create large gravitational forces. But Earth's mass is extremely large. As a result, the force of gravity between Earth and objects on Earth is very strong. That's why objects fall to the ground when you drop them.

Gravitational force is weaker when the distance between the objects is farther. The sun's mass is many times larger than Earth's, but you do not feel its attraction. This is because of the enormous distance between you and the sun.

Weight is a measure of the gravitational force on an object. It is measured in newtons (N). Weight is not the same as mass. Mass is the amount of matter in an object and is measured in kilograms (kg). Weight varies depending on the force of gravity, but mass does not change. The illustrations shows that the astronaut's mass is the same when measured on Earth and on the moon. But her weight is different. Her weight is much larger on Earth because Earth is much more massive than the moon.

Falling objects are accelerated by gravity. All objects falling to Earth's surface accelerate at a rate of 9.8 m/s^2.



Acceleration due to gravity

Show What You Know

What two factors does the force of gravity depend on?

1. _____

2. _____

LESSON 87

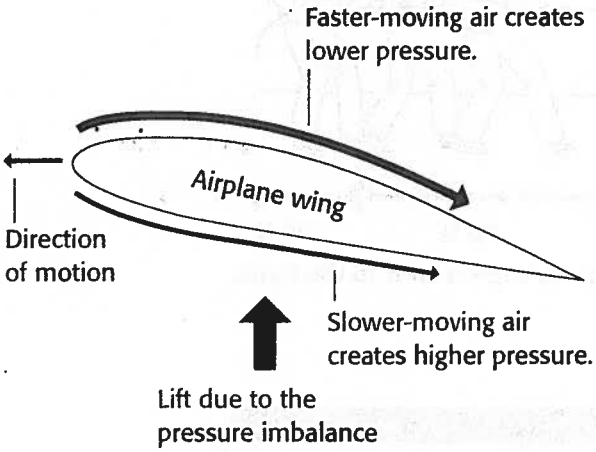
Forces in Fluids

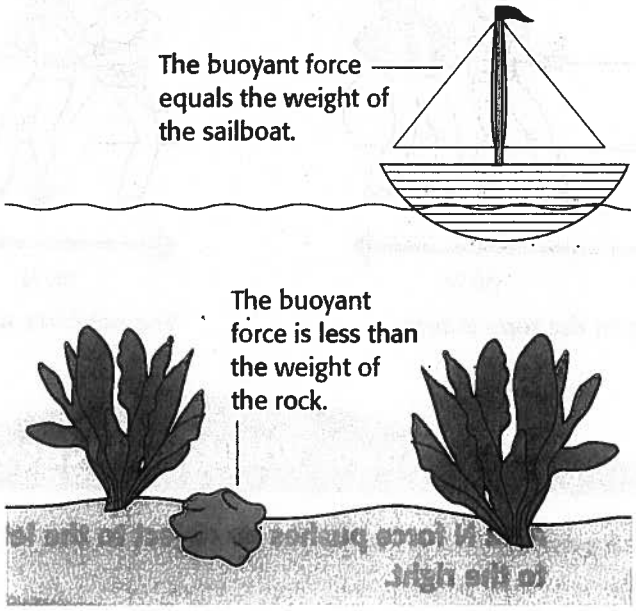
What makes airplanes fly and steel ships float?

A **fluid** is any material that can flow easily. Air and water are both fluids. All fluids exert **pressure**. Pressure is measured in **pascals**. One **pascal** is the force of one newton pushing on an area of one square meter, or 1 N/m^2.

Air exerts pressure. But slower-moving air exerts more pressure than faster-moving air. Airplane wings are designed so that air flows faster over them than it does beneath them. That means the pressure exerted beneath each wing is greater than the pressure exerted on the top of each wing, so the wings are pushed upward. This upward force is called **lift.**

Buoyant force is also an upward force. It is the force a fluid exerts on an object. It is equal to the weight of the fluid that an object displaces. If the buoyant force is less than an object's weight, the object will sink. If the buoyant force is equal to an object's weight, the object will float.





Show What You Know

The hulls of steel ships are hollowed out so that they displace a lot of water. How does this allow them to float?

_____

_____

_____

LESSON

88

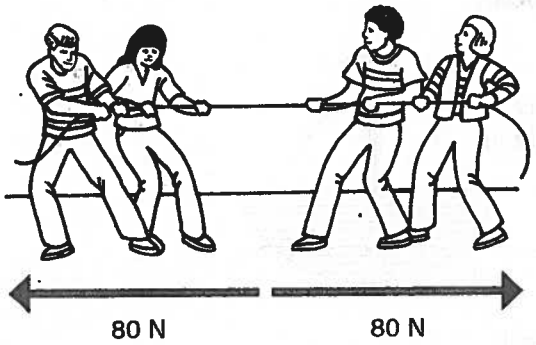
Net Forces

What happens when more than one force acts on an object?

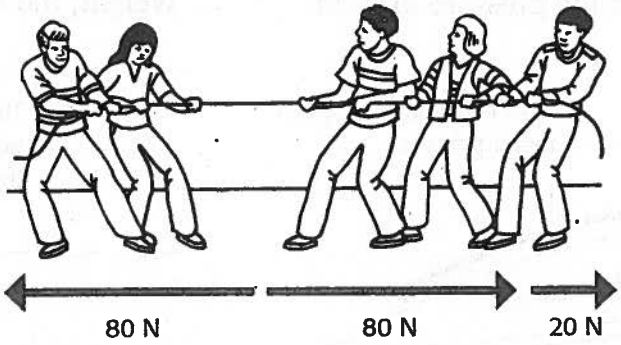
More than one force can act on an object at one time. The **net force** on an object is the sum of all the forces on the object. If the net force acting on an object is not zero, the force will cause a change in motion.

Look at the tug-of-war shown below. Both teams pull with a force of 80 newtons (N). The forces are equal in size and act in opposite directions. When added together, the net force is zero. The rope does not move and neither team wins.

Suppose another person joins the team on the right and pulls with an additional force of 20 N. Now the sum of the forces acting on the rope is 20 N to the right. The rope moves to the right and the team on the right wins.



The net force acting on the rope is zero.



The net force acting on the rope is 20 N to the right.

Show What You Know

A 12 N force pushes an object to the left. A 10 N force pushes the same object to the right.

1. Draw and label a picture to show the forces acting on the object.

2. What is the magnitude (amount) and direction of the net force?

_____

LESSON 89

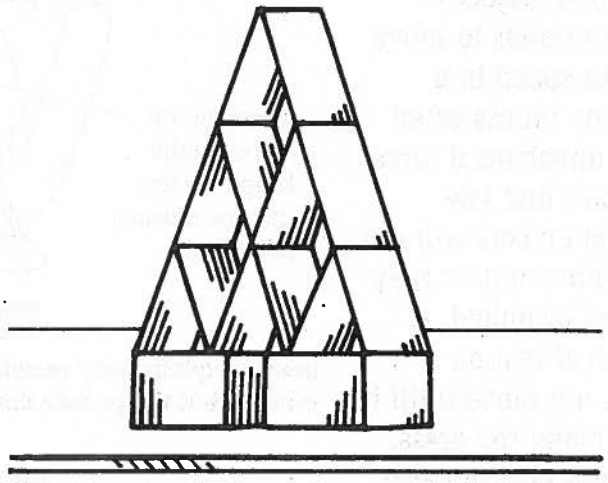
Balanced and Unbalanced Forces

When do forces cause a change in motion?

An object can have more than one force acting on it. If all of the forces acting on an object are balanced, the net force is zero. The object will not experience a change in motion. **Balanced forces** do not cause a change in motion. If an object is at rest, it will remain at rest. If it is in motion, it will remain in motion.

Think about a house of cards. The cards are carefully stacked on top of one another to form a pyramid shape. None of the cards is moving. Because the cards are not moving, you can infer that all the forces acting on them are balanced.

The card house will remain standing until an unbalanced force—like a bump on the table—makes it collapse. **Unbalanced forces** cause a change in motion. They can make objects at rest start moving, or moving objects change their direction or speed. A kick is an unbalanced force that makes a soccer ball start rolling. A kick can also change the direction of a soccer ball that is already rolling.



Balanced forces

Show What You Know

1. How can you tell if the forces acting on an object are balanced or unbalanced?

_____

_____

2. List two changes an unbalanced force can cause.

a. _____

b. _____

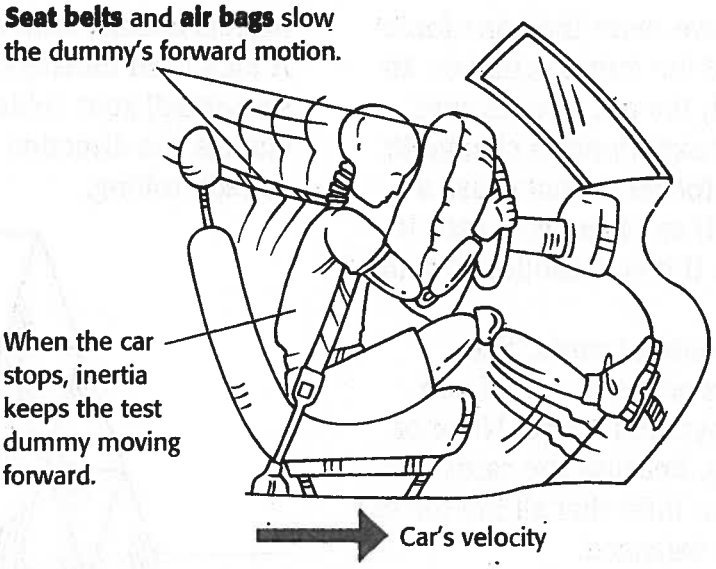
LESSON 90

Newton's First Law

What is inertia?

Newton's first law of motion is usually stated in this way: An object at rest remains at rest unless acted on by an unbalanced force. And an object in motion continues to move at constant speed in a straight line unless acted on by an unbalanced force.

Newton's first law means that objects will not begin to move unless they are pushed or pulled. A soccer ball at rest on a field does not move until it is kicked along the grass.



Inertia explains why people get injured in car crashes. The car stops moving, but the people don't.

Newton's first law also says that once the soccer ball is set in motion, it will stay in motion with the same velocity forever. Obviously, this is not what you observe in a soccer game or in the motion of any object on Earth. Moving objects ordinarily encounter friction, an unbalanced force that slows and eventually stops their motion.

Newton's first law is often called the law of inertia. **Inertia** is the tendency of an object to resist a change in its motion. Inertia is related to mass. Objects with more mass have more inertia than those with less mass.

Show What You Know

Complete the following sentences.

1. Newton's first law is also known as _____.
2. An object at rest will remain at rest until it is acted upon by

   _____.
3. Inertia is the tendency of an object to resist _____.

LESSON 91

Newton's Second Law

How are force and mass related to acceleration?

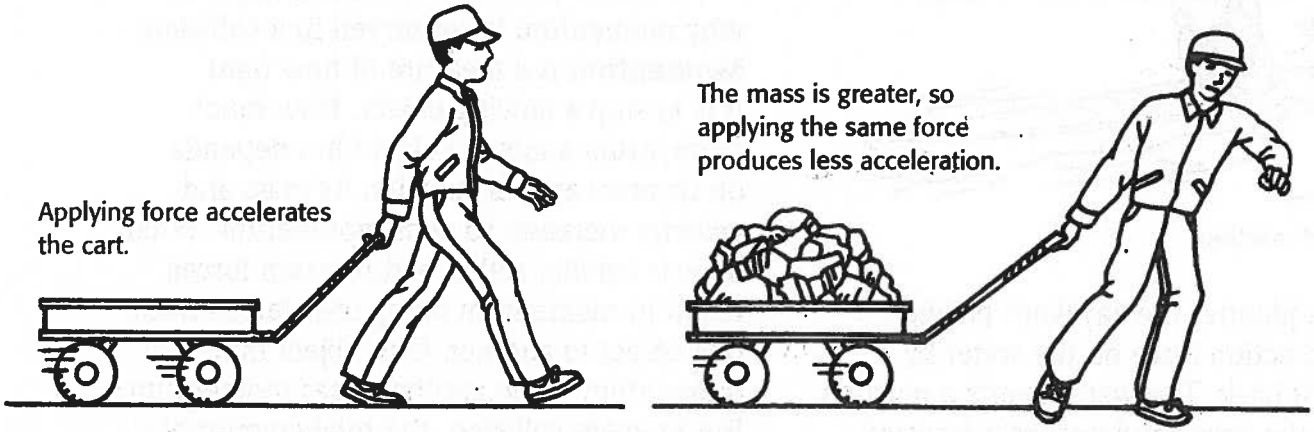
Newton's second law of motion says that the greater the unbalanced force acting on an object, the greater the acceleration of the object. It also says that an unbalanced force applied to a smaller mass will produce a greater acceleration than the same force applied to a larger mass.

Newton's second law can be summarized in this equation:

$$\text{acceleration} = \frac{\text{Force}}{\text{mass}} \text{ or } a = \frac{F}{m}$$

The equation can also be rearranged to solve for force (F):

$$F = m \times a$$



Acceleration depends on mass.

Show What You Know

1. What is the acceleration of a bowling ball with a mass of 4.0 kg when a force of 20 N acts on it? (The unit N is equal to the units kg·m/s^2.)

2. What force is needed to accelerate a 1,000 kg car at 4 m/s^2?

LESSON 92

Newton's Third Law

What are action and reaction forces?

Newton's third law of motion is often called the **law of action and reaction.** The law states that forces come in pairs. Whenever one object exerts a force on a second object, the second object exerts a force on the first object that is equal in magnitude and opposite in direction.

Action and reaction

In the picture, the kayaker's paddle exerts an action force on the water by pushing it back. The water exerts a reaction force on the kayak and pushes it forward. The two forces are equal in magnitude and opposite in direction. But the forces do not act on the same object. If they did, they would cancel each other and no motion would result.

Action/reaction force pairs do not always cause motion. If you lean against a wall, you exert a force on the wall. The wall presses back on you with an equal and opposite force. The forces cancel each other and no motion occurs.

Newton's third law of motion explains why momentum is conserved in a collision. **Momentum** is a measure of how hard it is to stop a moving object. How much momentum a moving object has depends on its mass and its velocity. As mass and velocity increase, so does momentum. When objects collide, action and reaction forces result in momentum being transferred from one object to another. One object may gain momentum while another loses momentum. But in every collision, the total amount of momentum remains the same.

Show What You Know

1. Label the action and reaction forces in the picture above.

2. Now draw arrows and label the action and reaction forces in the picture below.