

Newton's First and Second Laws

KEY IDEAS

As you read this section, keep these questions in mind:

- What makes an object's motion change?
- What is inertia?
- What affects how much an object speeds up or slows down?

What Are Newton's Laws of Motion?

Imagine rolling a basketball across a smooth wooden floor. How far will the ball roll before it stops? Now imagine rolling the ball across a floor covered with carpet. The ball will not roll as far on the carpet as it did on the smooth floor. What causes this?

Hundreds of years ago, an English scientist named Sir Isaac Newton noticed similar effects. He also wondered what caused them. He discovered the relationship between motion and forces. He described the relationships in three laws. Today, we call these laws *Newton's laws of motion*.

What Is Newton's First Law of Motion?

A ball that stops after rolling along the floor is an example of Newton's first law of motion. This law states that an object's motion will not change until an unbalanced force acts on the object. The law also states that an object will not start to move until an unbalanced force acts on it. A rolling ball stops moving because the force of friction acts on it and slows it down. If there were no friction, the ball would keep rolling. ✓



This bowling ball slows down as it rolls because of the force of friction. If no forces acted on the ball, it would not stop rolling.

READING TOOLBOX

Find Examples As you read, make a table listing examples of Newton's first and second laws.

READING CHECK

1. Describe State Newton's first law of motion in your own words.

SECTION 1 Newton's First and Second Laws *continued*

What Is Inertia?

Another way of stating Newton's first law is that matter resists any change in motion. All objects resist changes in motion. However, not all objects resist changes in motion by the same amount. For example, it does not take very much force to change the motion of a baseball. It takes much more force to change the motion of a bowling ball. The bowling ball resists changes in motion more than the baseball does.

The tendency of an object to resist changes in motion is called **inertia**. All objects have inertia. The amount of inertia an object has depends on the object's mass. The greater the mass of an object, the greater its inertia. ✓

READING CHECK

2. Explain How is mass related to inertia?

SEAT BELTS AND CAR SEATS

Think about the last time you rode in a car. What happened when the car stopped suddenly? You probably felt like you were being pushed toward the front of the car. Objects in the seats near you may have fallen over. Newton's first law of motion explains why this happens.

When a car stops, the inertia of the objects inside the car prevents them from stopping right away. Therefore, they may slide or fall over as the car stops suddenly.

Seat belts help to protect people inside a car from being hurt when the car stops. When the car stops, you start to slide toward the front of the car. The seat belt catches you and stops you from sliding.

Car seats help keep babies from being hurt when a car stops. These seats face toward the back of the car, as you can see in the figure below. This kind of car seat keeps the baby from sliding forward.



Car seats like this one help prevent babies from being hurt when a car stops.

LOOKING CLOSER

3. Describe How does the car seat protect the baby?

SECTION 1 Newton's First and Second Laws *continued***What Is Newton's Second Law of Motion?**

Newton's first law describes what happens when no unbalanced forces act on an object: the object's motion does not change. What happens when an unbalanced force does act on an object?

Newton's second law states that the larger the unbalanced force on an object, the more the object's motion will change. It also states that the larger the object's mass, the smaller its acceleration will be. *Acceleration* is the change in motion of an object.

Think about a baseball. If you throw the baseball gently, it will not move very fast. If you throw it more forcefully, it will move much more quickly. Now, imagine using the same force to throw a bowling ball. What will happen? The bowling ball will move much more slowly than the baseball.

We can write Newton's second law of motion as a mathematical equation:

$$\text{net force} = \text{mass} \times \text{acceleration}$$

or

$$F = ma$$

You can use this equation to calculate how much force is needed to make an object accelerate. You can also use it to calculate how much an object will accelerate when a force acts on it. Before you can use the equation, though, you need to know how scientists measure force.

What Are the Units of Force?

The SI unit scientists use to measure force is the newton (N). One newton is the amount of force needed to make a one-kilogram mass accelerate at one meter per second squared:

$$1 \text{ N} = 1 \text{ kg} \times 1 \text{ m/s}^2$$

Although scientists use newtons to measure force, sometimes people use pounds instead. One pound (lb) is equal to 4.45 N. One newton is equal to 0.225 lb.

Units of force	
newtons (N)	1 N = 1 kg × m/s ² 1 N = 0.225 lb
pounds (lb)	1 lb = 4.45 N 1 lb = 4.45 kg × m/s ²

Critical Thinking

4. Apply Concepts In many cases, large trucks move more slowly up hills than small cars. What do you think is the reason for this?

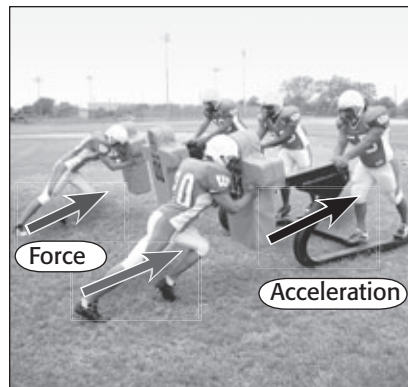
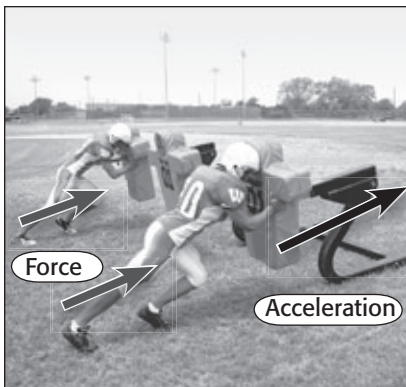
LOOKING CLOSER

5. Calculate How many newtons are equal to 10 lb?

SECTION 1 Newton's First and Second Laws *continued*

How Does Mass Affect Acceleration?

Look at the two pictures below. The football players are pushing with the same amount of force in both pictures. However, the mass of the sled is smaller in the picture on the left than the one in the picture on the right. Therefore, the sled on the left accelerates more than the one on the right.



The sled on the left accelerates more because its mass is smaller.

LOOKING CLOSER

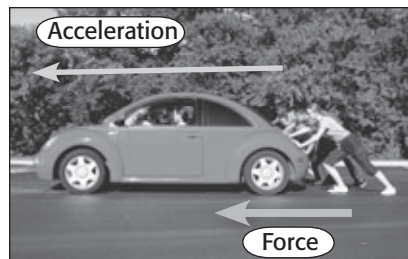
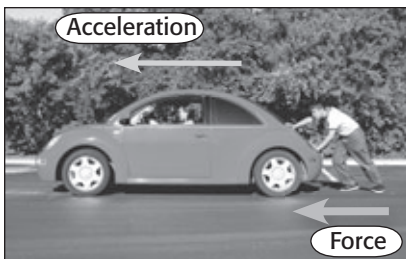
6. Infer What could the football players pushing the sled do to make it move more quickly?

Talk About It

Give Examples In a small group, talk about times you have seen examples of Newton's second law of motion.

How Does Force Affect Acceleration?

Look at the other two pictures below. In the picture on the left, one person is pushing the car. The car has a large mass, and it does not accelerate very much. In the picture on the right, several people are pushing the same car. The mass of the car is the same as in the left-hand picture. However, the force is greater. Therefore, the car on the right accelerates more.



The car in the right-hand picture accelerates more because the force acting on it is greater.

LOOKING CLOSER

7. Infer What would happen if the mass of the car on the right was greater?

SECTION 1 Newton's First and Second Laws *continued***CALCULATING FORCE FROM ACCELERATION**

Zoo keepers lift a lion on a stretcher. The total mass of the lion and the stretcher is 175 kg. The acceleration of the lion and the stretcher is 0.657 m/s^2 upward. What force do the zoo keepers use to produce this acceleration?

Step 1: List the given and unknown values.	Given: mass, $m = 175 \text{ kg}$ acceleration, $a = 0.657 \text{ m/s}^2$	Unknown: force, F
Step 2: Write the equation.	$F = ma$	
Step 3: Insert the known values and solve for the unknown value.	$F = (175 \text{ kg}) \times (0.657 \text{ m/s}^2)$ $F = 115 \text{ kg} \times \text{m/s}^2 = 115 \text{ N}$	

So, the zoo keepers apply 115 N of force to lift the lion and the stretcher.

CALCULATING ACCELERATION FROM FORCE

A sailboat has a mass of 655 kg. A force of 895 N pushes the sailboat forward. What is the sailboat's acceleration?

Step 1: List the given and unknown values.	Given: mass, $m = 655 \text{ kg}$ force, $F = 895 \text{ N}$	Unknown: acceleration, a
Step 2: Write the equations.	$F = ma$ $a = \frac{F}{m}$	
Step 3: Insert the known values and solve for the unknown value.	$a = \frac{895 \text{ N}}{655 \text{ kg}} = \frac{895 \text{ kg} \times \text{m/s}^2}{655 \text{ kg}}$ $a = 1.37 \text{ m/s}^2$	

So, the sailboat accelerates at 1.37 m/s^2 .

Math Skills

8. Calculate An object with a mass of 10.0 kg accelerates upward at 5.0 m/s^2 . What force acts on the object? Show your work.

Math Skills

9. Manipulate Equations Show how to rearrange the equation for Newton's second law of motion in order to solve for mass.

Section 1 Review

SECTION VOCABULARY

inertia the tendency of an object to resist a change in motion unless an outside force acts on the object	
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1. Apply Concepts Which has more inertia, a car with a mass of 900 kg or a car with a mass of 1,500 kg? Explain your answer.

2. Infer Newton’s first law of motion is sometimes called the “law of inertia.” Why?

3. List Give two examples of Newton’s second law of motion.

4. Calculate A baseball accelerates downward at 9.8 m/s^2 . The force pulling the ball downward is 1.4 N. What is the mass of the baseball? Show your work.

5. Calculate A model airplane has a mass of 3.2 kg. Its propeller pulls it forward with a force of 7.0 N. What is the airplane’s acceleration? Show your work.

6. Make Predictions Two cars are driving at the same speed. The cars have the same mass. One car is driving on an icy road. The other is driving on a dry road. Which car will be able to stop more quickly? Explain your answer.
