

Newton's First and Second Laws

Reading Preview

Key Concepts

- What is Newton's first law of motion?
- What is Newton's second law of motion?

Key Term

- inertia

Target Reading Skill

Outlining As you read, make an outline about Newton's first and second laws. Use the red headings for the main topics and the blue headings for the subtopics.

Newton's First and Second Laws

- I. The first law of motion
 - A. Inertia
 - B.
- II. The second law of motion
 - A.

Isaac Newton ▼



Lab zone Discover Activity



What Changes Motion?

1. Stack several metal washers on top of a toy car.
2. Place a heavy book on the floor near the car.
3. Predict what will happen to both the car and the washers if you roll the car into the book. Test your prediction.

Think It Over

Observing What happened to the car when it hit the book? What happened to the washers? What might be the reason for any difference between the motions of the car and the washers?

How and why objects move as they do has fascinated scientists for thousands of years. In the early 1600s, the Italian astronomer Galileo Galilei suggested that, once an object is in motion, no force is needed to keep it moving. Force is needed only to change the motion of an object. Galileo's ideas paved the way for Isaac Newton. Newton proposed the three basic laws of motion in the late 1600s.

The First Law of Motion

Newton's first law restates Galileo's ideas about force and motion. **Newton's first law of motion states that an object at rest will remain at rest, and an object moving at a constant velocity will continue moving at a constant velocity, unless it is acted upon by an unbalanced force.**

If an object is not moving, it will not move until a force acts on it. Clothes on the floor of your room, for example, will stay there unless you pick them up. If an object is already moving, it will continue to move at a constant velocity until a force acts to change either its speed or direction. For example, a tennis ball flies through the air once you hit it with a racket. If your friend doesn't hit the ball back, the forces of gravity and friction will eventually stop the ball. On Earth, gravity and friction are unbalanced forces that often change an object's motion.

FIGURE 13
Inertia The inertia of the objects on the table keeps them from moving. *inferring Why should the girl use a slippery tablecloth?*



Inertia Whether an object is moving or not, it resists any change to its motion. Galileo's concept of the resistance to a change in motion is called inertia. **Inertia** (in UR shuh) is the tendency of an object to resist a change in motion. Newton's first law of motion is also called the law of inertia.

Inertia explains many common events, such as why you move forward in your seat when a car stops suddenly. When the car stops, inertia keeps you moving forward. A force, such as the pull of a seat belt, is required to change your motion.

Inertia Depends on Mass Some objects have more inertia than other objects. For example, suppose you needed to move an empty aquarium and an aquarium full of water. Obviously, the full aquarium is harder to move than the empty one, because it has more mass. The greater the mass of an object is, the greater its inertia, and the greater the force required to change its motion. The full aquarium is more difficult to move because it has more inertia than the empty aquarium.



How is mass related to inertia?

Try This Activity

Around and Around
 An object moving in a circle has inertia.

1. Tape one end of a length of thread (about 1 m) to a table tennis ball.
2. Suspend the ball in front of you and swing it in a horizontal circle, keeping it 2–3 cm above the floor.
3. Let go of the thread and observe the direction in which the ball rolls.
4. Repeat this several times, letting go of the thread at different points.

Inferring At what point do you need to let go of the thread if you want the ball to roll directly away from you? Toward you? Draw a diagram as part of your answer.

The Second Law of Motion

Suppose you are baby-sitting two children who love wagon rides. Their favorite part is when you accelerate quickly. When you get tired and sit in the wagon, one of the children pulls you. He soon finds he cannot accelerate the wagon nearly as fast as you can. How is the wagon's acceleration related to the force pulling it? How is the acceleration related to the wagon's mass?

Determining Acceleration According to Newton's second law of motion, acceleration depends on the object's mass and on the net force acting on the object. This relationship can be written as an equation.

$$\text{Acceleration} = \frac{\text{Net force}}{\text{Mass}}$$

Acceleration is measured in meters per second per second (m/s^2), and mass is measured in kilograms (kg). According to Newton's second law, then, force is measured in kilograms times meters per second per second ($\text{kg} \cdot \text{m/s}^2$). The short form for this unit of force is the newton (N). Recall that a newton is the SI unit of force. You can think of 1 newton as the force required to give a 1-kg mass an acceleration of 1 m/s^2 .

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Math Sample Problem

Calculating Force

A speedboat pulls a 55-kg water-skier. The force causes the skier to accelerate at 2.0 m/s^2 . Calculate the net force that causes this acceleration.

1 Read and Understand

What information are you given?

Mass of the water-skier (m) = 55 kg

Acceleration of the water-skier (a) = 2.0 m/s^2

2 Plan and Solve

What quantity are you trying to calculate?

The net force (F_{net}) = ?

What formula contains the given quantities and the unknown quantity?

$$a = \frac{F_{\text{net}}}{m} \quad \text{or} \quad F_{\text{net}} = m \times a$$

Perform the calculation.

$$F_{\text{net}} = m \times a = 55 \text{ kg} \times 2.0 \text{ m/s}^2$$

$$F = 110 \text{ kg} \cdot \text{m/s}^2$$

$$F = 110 \text{ N}$$

3 Look Back and Check

Does your answer make sense?

A net force of 110 N is required to accelerate the water-skier. This may not seem like enough force, but it does not include the force of the speedboat's pull that overcomes friction.



Math Practice

1. **Calculating Force** What is the net force on a 1,000-kg object accelerating at 3 m/s^2 ?
2. **Calculating Force** What net force is needed to accelerate a 25-kg cart at 14 m/s^2 ?

FIGURE 14

Force and Mass

The force of the boy's pull and the mass of the wagon determine the wagon's acceleration.



Changes in Force and Mass How can you increase the acceleration of the wagon? Look again at the equation. One way to increase acceleration is by changing the force. If the mass is constant, acceleration and force change in the same way. So to increase the acceleration of the wagon, you can increase the force used to pull it.

Another way to increase acceleration is to change the mass. According to the equation, acceleration and mass change in opposite ways. If the force is constant, an increase in mass causes a decrease in acceleration. The opposite is also true: A decrease in mass causes an increase in acceleration with a constant force. To increase the acceleration of the wagon, you can decrease its mass. So, instead of you, the children should ride in the wagon.



Reading Checkpoint

What are two ways to increase the acceleration of an object?

Section 3 Assessment

Target Reading Skill Outlining Use the information in your outline about Newton's first and second laws of motion to help you answer the questions below.

Reviewing Key Concepts

1. **a. Reviewing** What does Newton's first law of motion state?
- b. Explaining** Why is Newton's first law of motion sometimes called the law of inertia?
- c. Inferring** Use what you know about inertia to explain why you feel pressed back into the seat of a car when it accelerates.
2. **a. Defining** State Newton's second law of motion in your own words.
- b. Problem Solving** How could you keep an object's acceleration the same if the force acting on the object were doubled?

- c. Applying Concepts** Using what you know about Newton's second law, explain why a car with a large mass might use more fuel than a car with a smaller mass. Assume both cars drive the same distance.

Math

Practice

3. **Calculating Force** Find the force it would take to accelerate an 800-kg car at a rate of 5 m/s^2 .
4. **Calculating Force** What is the net force acting on a 0.15-kg hockey puck accelerating at a rate of 12 m/s^2 ?