Section 3

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. Newton's first law
  A. Inertia
  B.
II. Newton's second law
  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.

Lab zone Discover Activity

Skills Focus Observing L1

Materials heavy book, metal washers, toy car

Time 10 minutes

Tips Students should be reminded not to fasten the washers to the top of the car.

Expected Outcome The car will stop or bounce backward when it hits the book. The washers will continue to move forward.

Think It Over The car stopped or bounced back when it hit the book, while the washers kept moving forward. The book exerted a force on the car that caused it to stop, however the book did not exert a force on the washers, so they continued moving.

Section 3

Newton's First and Second Laws

Objectives

After this lesson, students will be able to

M.2.3.1 State Newton's first law of motion.

M.2.3.2 State Newton's second law of motion.

Target Reading Skill

Outlining Explain that using an outline format helps students organize information by main topic, subtopic, and details.

Answers

Newton's First and Second Laws

I. The first law of motion
  A. Inertia
  B. Inertia depends on mass

II. The second law of motion
  A. Changes in force and mass

All in One Teaching Resources

- Transparency M15

Preteach

Build Background Knowledge L2

Force Affects Acceleration

Demonstrate the effect of force on acceleration by placing one end of a flexible ruler next to a golf ball, bending the ruler back slightly, and releasing it to exert a small force on the ball. Repeat the demonstration, but bend the ruler back further so it exerts a greater force against the ball. Have students compare the forces and the motion of the ball in each trial.

Instruct

The First Law of Motion

Teach Key Concepts L2

Force and Motion

Focus Ask: **What happens to passengers when a car stops quickly?** *(Sample answer: They keep moving until the seatbelt stops them.)*

Teach Explain that an object's motion does not change unless it is acted upon by unbalanced forces. Resistance to a change in motion is called inertia.

Apply Ask: **How does Newton's first law explain what happens to passengers when a car stops quickly?** *(Sample answer: The passengers keep moving until acted upon by the unbalanced force exerted by the seatbelt.)* **learning modality: logical/mathematical**

The Second Law of Motion

Teach Key Concepts L2

Force, Mass and Acceleration

Focus Have students recall experiences of pushing a grocery cart. Ask: **Would you need to exert more force to move a full cart or an empty cart?** *(A full cart)*

Teach Remind students that a full grocery cart has more mass than an empty cart. Newton's second law states the relationship between force, mass, and acceleration. The greater the mass, the more force that is required to produce a certain acceleration.

Apply Ask: **How could you make grocery carts with different masses have the same acceleration?** *(You would need to exert different forces on the carts.)* **learning modality: logical/mathematical**

Independent Practice L2

All in One Teaching Resources

- Guided Reading and Study Worksheet: *Newton's First and Second Laws*

Student Edition on Audio CD

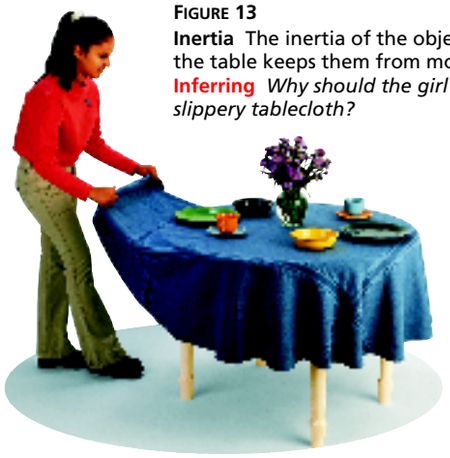

FIGURE 13
Inertia The inertia of the objects on the table keeps them from moving. **Inferring** *Why should the girl use a slippery tablecloth?*

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.

Reading Checkpoint **How is mass related to inertia?**

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?

Lab zone **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.

Lab zone **Try This Activity**

Skills Focus Inferring

Materials masking or cellophane tape, table tennis ball, thread

Time 15 minutes

L2 **Expected Outcome** The ball will continue to travel in the direction in which it was moving when it was released. Students' diagrams should show that the ball must be released when it is moving in the desired direction. **learning modality: kinesthetic**

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 ($kg \cdot m/s^2$). The short form for this unit of force is the newton (N). Recall from Section 1 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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Visit: PHSchool.com
Web Code: cgd-3023

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?

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

Perform the calculation.

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

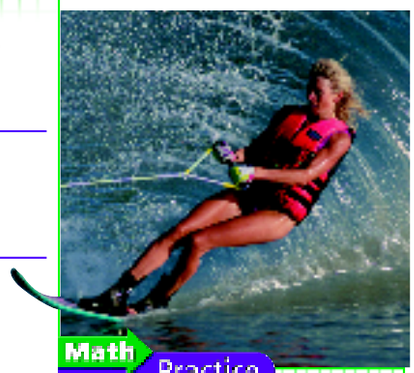
$F = 110\ kg \cdot m/s^2$

$F = 110$ 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?

Differentiated Instruction

Less Proficient Readers L1

Asking Questions Have students listen to the section on the **Student Edition on Audio CD.** Then have students locate the headings in the section. Have students phrase the headings in the form of a question, and share the answers verbally. **learning modality: verbal**

Lab zone Teacher Demo

Newton's Second Law L1

Materials 1-kg mass, spring scale

Time 10 minutes

Focus Remind students that 1 N equals the force needed to accelerate a 1-kg mass at a rate of 1 m/s^2.

Teach Demonstrate 1 N of force by attaching the spring scale to the 1-kg mass and dragging the mass along the table. You can minimize friction by pulling the mass over oil or beads.

Apply Ask: **How can you determine the amount of force it took to pull the mass?** *(Look at the measurement on the spring scale.)* **How could you make the mass accelerate at a greater rate?** *(Pull the mass with more force.)* **learning modality: visual**

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Web Code: cgd-3023

Students can research Newton's laws online.

Math Sample Problem

Math Skill Calculating force

Focus Remind students that force equals mass multiplied by acceleration.

Teach Remind students to enter the known values into the provided formula. They can then solve for the unknown value. Remind students to perform the same operation on the units that they do on the numbers.

Answers

1. 3,000 N (1,000 kg × 3 m/s^2)

2. 350 N (25 kg × 14 m/s^2)

All in One Teaching Resources

- Transparency M16

Monitor Progress L2

Skills Check Have students calculate the force needed to accelerate a 25-kg crate of books at a rate of 3.0 m/s^2. *(Force = 25 kg × 3.0 m/s^2 = 75 N)*

Answers

Figure 13 To reduce static and sliding friction

Reading Checkpoint Mass is directly related to inertia. The greater the mass of an object, the greater is its inertia.

Monitor Progress L2

Answers

Reading Checkpoint To increase acceleration you can decrease mass or increase force.

Assess

Reviewing Key Concepts

1. a. Unless acted upon by an unbalanced force, an object at rest will remain at rest and an object in motion at a constant velocity will continue moving at a constant velocity. **b.** Inertia is a measure of an object's tendency to resist a change in its motion, a statement that has the same meaning as Newton's first law of motion. **c.** Because of your inertia, your body tends to remain in place. The car seat causes you to accelerate, therefore, by exerting a force on your back. **2. a.** Sample answer: When accelerating an object by applying a force, the greater the force, the greater the acceleration or the greater the object's mass, the lower the acceleration. **b.** You could double the object's mass. **c.** A greater force is required to accelerate a more massive car, therefore, more engine power is required and more fuel is needed to produce that power.

Reteach L1

Have students write Newton's first and second laws in their own words. Ask volunteers to share their answers with the class.

Performance Assessment L2

Oral Presentation Have students explain why the same force accelerates an empty wagon more than a wagon full of bricks. *(According to Newton's second law, if the mass is smaller, acceleration is larger for the same amount of force.)*

All in One Teaching Resources

- Section Summary: *Newton's First and Second Laws*
- Review and Reinforcement: *Newton's First and Second Laws*
- Enrich: *Newton's First and Second Laws*

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?

Math Practice

Math Skill Calculating force

Answers

3. 4,000 N (800 kg × 5 m/s^2)
4. 1.8 N (0.15 kg × 12 m/s^2)

Lab zone Chapter Project

Keep Students on Track Remind students that their vehicles will need to accelerate from a resting position. From Newton's second law of motion, the students know that acceleration can be increased two ways: by decreasing the mass of the vehicle or by increasing the force acting on the vehicle. Have students work in small groups to brainstorm ways of increasing force or decreasing mass.