Section 1
What Is Magnetism?

Objectives
After this lesson, students will be able to

N.1.1.1 Explain what the properties of a magnet are.

N.1.1.2 Explain how magnetic poles interact.

N.1.1.3 Describe the shape of a magnetic field.

Target Reading Skill
Using Prior Knowledge Explain that using prior knowledge helps students connect what they already know to what they are about to read.

Answers

Possible answers:

What You Know:

1. Magnets stick to refrigerators.
2. Magnets have north and south poles.
3. Magnets have magnetic fields around them.

What You Learned:

1. A magnet attracts iron and materials that contain iron.
2. Magnetic poles that are alike repel each other, and magnetic poles that are unlike attract each other.
3. Magnetic forces are exerted all around a magnet, and magnets can interact without touching.

All in One Teaching Resources
- Transparency N1

Preteach

Build Background Knowledge
L2

Magnets in the Kitchen

Challenge students to think about how magnets are used in the kitchen. Ask: **What often keeps kitchen cabinet doors closed?** *(Sample answer: A small magnet on the edge of the cabinet attracts a small piece of metal on the inside of the door, keeping the door closed.)* **What holds the top of a can to an electric can opener after the top has been cut off?** *(A magnet)* **What holds notes on the front of a refrigerator?** *(Magnets)*

Section 1
What Is Magnetism?

Reading Preview

Key Concepts
- What are the properties of a magnet?
- How do magnetic poles interact?
- What is the shape of a magnetic field?

Key Terms
- magnet
- magnetic pole
- magnetic force
- magnetic field
- magnetic field lines

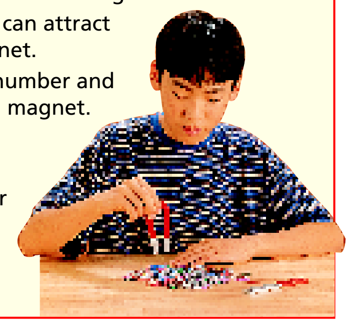
Target Reading Skill
Using Prior Knowledge Before you read, look at the headings and visuals to see what this section is about. Then write what you know about magnetism in a graphic organizer like the one below. As you read, write what you learn.

What You Know
1. Magnets stick to refrigerators. 2.

What You Learned
1. 2.

Lab zone Discover Activity

What Do All Magnets Have in Common?
1. Obtain a bar magnet and a horseshoe magnet.
2. See how many paper clips you can attract to different parts of each magnet.
3. Draw a diagram showing the number and location of paper clips on each magnet.



Think It Over

Observing Where does each magnet hold the greatest number of paper clips? What similarities do you observe between the two magnets?

Imagine zooming along in a train that glides without even touching the ground. You feel no vibration and hear no noise from the steel tracks below. You can just sit back and relax as you speed toward your destination at nearly 500 kilometers per hour.

Are you dreaming? No, you are not. You are floating a few centimeters in the air on a magnetically levitating train, or maglev train. Although you have probably not ridden on such a train, they do exist. What makes them float? Believe it or not, it is magnetism that makes them float.

◀ **Strong magnets move this Japanese maglev train.**

Lab zone Discover Activity

Skills Focus Observing L1

Materials bar magnet, horseshoe magnet, paper clips

Time 15 minutes

Tips Tell students they will observe how two different types of magnets attract materials.

Expected Outcome Most paper clips will be attracted to the magnets' poles. Few or none will be attracted to the middle of the bar magnet or to the curved part of the horseshoe magnet.

Think It Over Sample answer: Most paper clips are attracted to the ends of the magnets. Most of the magnetic pull seems to come from the poles, or ends, of the bar magnet and the horseshoe magnet.

Properties of Magnets

When you think of magnets, you might think about the objects that hold notes to your refrigerator. But magnets can also be found in many other everyday items such as wallets, kitchen cabinets, and security tags at a store. A **magnet** is any material that attracts iron and materials that contain iron.

Magnets have many modern uses, but they are not new. More than 2,000 years ago, people living in the ancient Greek city of Magnesia (in what is now Turkey) discovered an unusual kind of rock. This kind of rock contained a mineral called magnetite. Both the word *magnetite* and the word *magnet* come from the name Magnesia. Rocks containing magnetite attracted materials that contained iron. They also attracted or repelled other magnetic rocks. The attraction or repulsion of magnetic materials is called magnetism.

About a thousand years ago, people in other parts of the world discovered another property of magnetic rocks. If they allowed such a rock to swing freely from a string, one part of the rock would always point in the same direction. That direction was toward the North Star, Polaris. This star is also called the leading star, or lodestar. For this reason, magnetic rocks are known as lodestones.

Magnets have the same properties as magnetic rocks. **Magnets attract iron and materials that contain iron. Magnets attract or repel other magnets. In addition, one part of a magnet will always point north when allowed to swing freely.**

Reading Checkpoint **What mineral found in rocks can attract materials containing iron?**

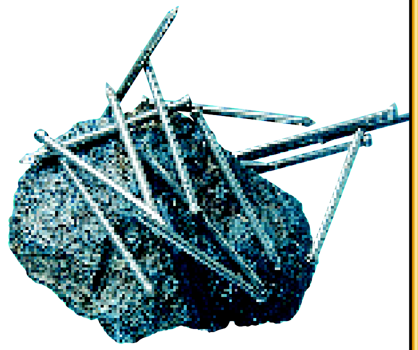


FIGURE 1
A Natural Magnet
Some magnets are found in nature. This rock attracts iron nails because it contains the magnetic mineral called magnetite.

FIGURE 2
Modern Magnets
Magnets come in a variety of shapes and sizes, but they share certain characteristics.
Inferring *What substance might the scissors, paper clips, and spoon have in common?*

Instruct

Properties of Magnets

Teach Key Concepts L2

The Attraction of Magnets

Focus Tell students that a magnet is any material that attracts iron or materials that contain iron.

Teach Ask: **What is magnetism?** *(The attraction or repulsion of magnetic materials)* **What are three properties of magnets?** *(Magnets attract iron and materials that contain iron. Magnets attract or repel other magnets. One part of a magnet always points north when allowed to swing freely.)*

Apply Have students look at Figure 1 and read the caption. Ask: **This rock is identified as a natural magnet. What do you know about this rock?** *(It attracts iron and materials that contain iron. It attracts or repels other magnets. One part of the rock will point north when allowed to swing freely.)* **learning modality: visual**

Independent Practice L2

All in One **Teaching Resources**

- *Guided Reading and Study Worksheet: What Is Magnetism?*

Student Edition on Audio CD

Monitor Progress L2

Writing Ask students to write a definition of magnetism in their own words.

Answers

Figure 2 The objects might contain iron.

Reading Checkpoint The mineral magnetite can attract materials containing iron.

Magnetic Poles

Teach Key Concepts

L2

A Magnet Has Two Poles

Focus Explain to students that any magnet always has two poles, called a north pole and a south pole.

Teach Show students a bar magnet on which the two poles are labeled. Ask: **What is each end of the magnet called?** *(A magnetic pole)* **Which part of this magnet will always point north if it hangs free on a string?** *(The north pole)* **What is the rule about what happens when the poles of two magnets are brought together?** *(Magnetic poles that are alike repel each other, and magnetic poles that are unlike attract each other.)*

Apply Show students a bar magnet. Ask: **If you bring this north pole near another magnet's north pole, what will happen?** *(The two like poles will push away from each other.)* **If you bring this south pole near another magnet's north pole, what will happen?** *(The two unlike poles will attract each other.)* **learning modality: verbal**

Lab zone Build Inquiry

L1

Attraction and Repulsion

Materials 2 bar magnets

Time 5 minutes

Focus Tell students that unlike poles attract each other and like poles repel each other.

Teach Have students place the magnets on their desks. Have them slide unlike poles of the magnets closer together until they can first feel the attraction. Then have them slide like poles of the magnets closer together until they can first feel the repulsion.

Apply Encourage students to experiment with the magnets to find out how close they can put unlike poles before the magnets are "pulled" together and how close they can put like poles before the magnets are "pushed" apart. **learning modality: kinesthetic**

FIGURE 3
Attraction and Repulsion
Two bar magnets suspended by strings are brought near each other. Unlike poles attract each other; like poles repel each other.
Predicting *What would happen if two south poles were brought near one another?*

Magnetic Poles

The magnets in your everyday life have the same properties as magnetic rocks because they are made to have them. Recall that one end of a magnet always points north. Any magnet, no matter what its shape, has two ends, each one called a **magnetic pole.** The magnetic effect of a magnet is strongest at the poles. The pole of a magnet that points north is labeled the north pole. The other pole is labeled the south pole. A magnet always has a pair of poles, a north pole and a south pole.

Magnetic Interactions What happens if you bring two magnets together? The answer depends on how you hold the poles of the magnets. If you bring the north pole of one magnet near the south pole of another, the two unlike poles attract one another. However, if you bring two north poles together, the like poles move away from each other. The same is true if two south poles are brought together. **Magnetic poles that are unlike attract each other, and magnetic poles that are alike repel each other.** Figure 3 shows how two bar magnets interact.

Magnetic Force The attraction or repulsion between magnetic poles is **magnetic force.** A force is a push or a pull that can cause an object to move. A magnetic force is produced when magnetic poles interact. Any material that exerts a magnetic force is considered to be a magnet.

The maglev train you read about earlier depends on magnetic force to move. Magnets in the bottom of the train and in the guideway on the ground have like poles facing each other. Because like poles repel, the two magnets move away from each other. The result is that the train car is lifted up, or levitated. Other magnets make the train move forward.

Reading Checkpoint **What does every magnet have in common?**

Lab zone Skills Activity

Observing

1. Use a pencil to poke a hole in the bottom of a foam cup. Turn the cup upside down and stand the pencil in the hole.
2. Place two circular magnets on the pencil, so that their like sides are together, and observe them.
3. Remove the top magnet. Flip it over, replace it on the pencil, and observe it.

What happens to the magnets in each case? Explain your observations.

Lab zone Skills Activity

Skills Focus Observing

L2

Materials pencil, foam cup, 2 circular magnets

Time 10 minutes

Tips Have students predict what will happen when they place the two magnets together on the pencil.

Expected Outcome In the first trial, the top magnet will levitate. The levitation is caused by the repulsion between like poles. In the second trial, the top magnet will be attracted to the bottom magnet. This is caused by the attraction of unlike poles.

Extend Have students use more magnets to increase the height of the levitating magnet. **learning modality: visual**

Magnetic Fields

A magnetic force is strongest at the poles of a magnet, but it is not limited to the poles. Magnetic forces are exerted all around a magnet. The area of magnetic force around a magnet is known as its **magnetic field.** Because of magnetic fields, magnets can interact without even touching.

Figure 4 shows the magnetic field of a bar magnet. Notice the red lines, called magnetic field lines, around the magnet. **Magnetic field lines** are invisible lines that map out the magnetic field around a magnet. **Magnetic field lines spread out from one pole, curve around the magnet, and return to the other pole.** The lines form complete loops from pole to pole and never cross. Arrows are used to indicate the direction of the magnetic field lines—always leaving the north pole and entering the south pole.

The distance between magnetic field lines indicates the strength of a magnetic field. The closer together the lines are, the stronger the field. A magnet's magnetic field lines are closest together at the poles.

Reading Checkpoint **Where is the magnetic field strongest?**

Go Online *active art*

For: Magnetic Field Lines activity
Visit: PHSchool.com
Web Code: cgp-4011

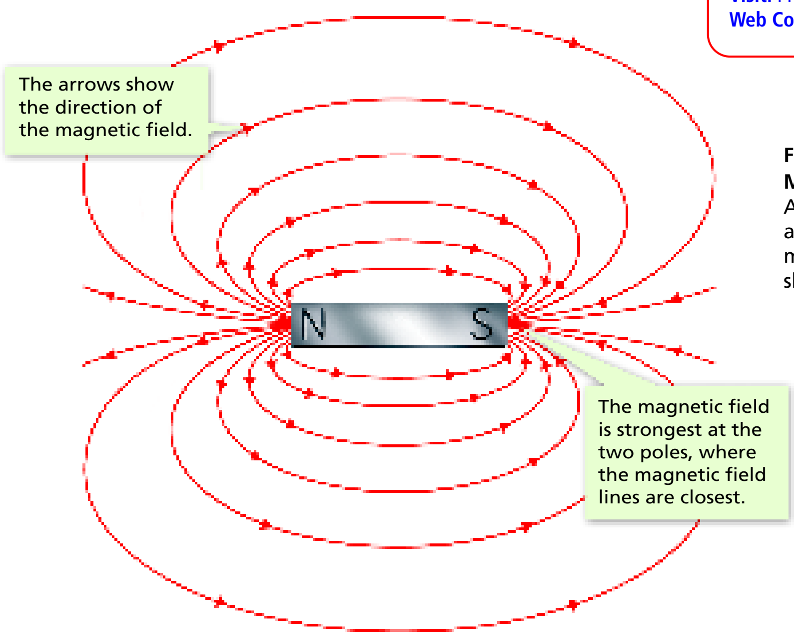


FIGURE 4
Magnetic Field Lines
A magnetic field surrounds a magnet. In this diagram, magnetic field lines are shown in red.

Magnetic Fields

Teach Key Concepts L2

An Area of Magnetic Force

Focus Tell students that magnetic forces are exerted all around a magnet.

Teach Ask: **What is a magnetic field?** *(The area of magnetic force around a magnet)* Explain that a force is a push or pull. Magnetic forces are exerted all around a magnet, but the forces are stronger in some areas. Ask: **Where are the magnetic forces of a magnet strongest?** *(Around the poles)* **In Figure 4, what are the lines around the magnet called?** *(Magnetic field lines)*

Apply Ask: **In Figure 4, how can you tell by the lines where this magnet's magnetic field is strongest?** *(The closer together the lines, the stronger the field. Therefore, the magnetic field is strongest near the poles.)*

Extend The ***active art*** shows how magnetic field lines spread out from one pole, curve around, and return to the other pole.
learning modality: visual

Go Online *active art*

For: Magnetic Fields Lines activity
Visit: PHSchool.com
Web Code: cgp-4011

Students can interact with the art of magnetic field lines online.

All in One Teaching Resources

- Transparency N2

Differentiated Instruction

Less Proficient Readers L1

Comprehension: Key Concept On the board, rewrite the boldface sentence about magnetic poles into two sentences: "Magnetic poles that are alike repel each other. Magnetic poles that are unlike attract each other." Then, review the meanings of *magnetic pole, attract,* and *repel*. Finally, use the illustrations in Figure 3 to clarify the meanings of the two sentences. **learning modality: verbal**

Monitor Progress L2

Answers

Figure 3 They would repel each other.

Reading Checkpoint Two magnetic poles

Reading Checkpoint At the poles

Using Visuals: Figure 5 L2

Magnetic Field Lines

Focus Tell students that iron filings can be used to map out a magnet's magnetic field.

Teach Have students observe the magnetic field lines in Figure 5. Ask: **Where does the field seem to be the strongest?** *(Around the poles)* **What evidence can you see for this conclusion?** *(The lines of iron filings are densest near the poles.)* **How can you tell that the magnet's magnetic field gets weaker farther from the magnet?** *(The iron filings are more spread out farther from the magnet.)*

Apply Challenge students to explain why the lines curve between the two poles. Ask: **Find an iron filing that is on the curve about halfway between the two poles. How are the forces acting at that point?** *(At that point, the filing is equally attracted to both poles.)* **learning modality: visual**

All in One Teaching Resources

- Transparency N3

Address Misconceptions L2

Contact Forces and Field Forces

Focus Some students may be confused by the concept of a magnetic field. Explain that scientists recognize two kinds of forces, contact forces and field forces.

Teach Tell students that contact forces act when two objects are in physical contact, but field forces can act without physically touching. Ask: **Is the force of gravity a contact force or a field force?** *(It is a field force, since it acts without objects being in physical contact.)*

Apply Have students look at the photo of iron filings around the bar magnet in Figure 5. Ask: **If the iron filings were not present around the magnet, would the field forces still be present around the poles of the magnet?** *(Yes, the field forces are always present. The iron filings simply make the effects of the field visible.)* **learning modality: verbal**

English Learners/Beginning L1
Comprehension: Ask Questions To help students understand the importance of

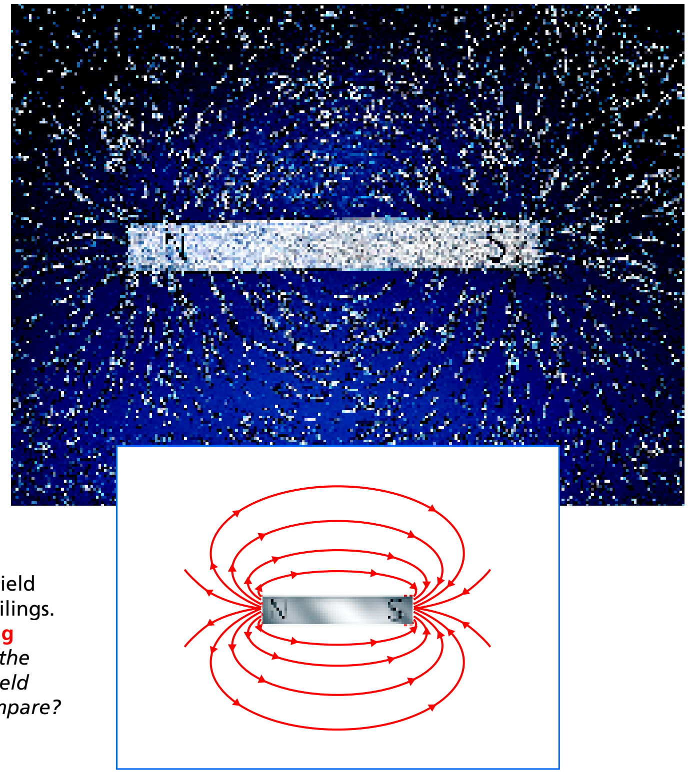


FIGURE 5
A Single Magnetic Field
A bar magnet's magnetic field is mapped out using iron filings.
Comparing and Contrasting
How do the iron filings in the photo and the magnetic field lines in the illustration compare?

A Single Magnetic Field Although you cannot see a magnetic field, you can see its effects. The photograph in Figure 5 shows iron filings sprinkled on a sheet of plastic that covers one magnet. The magnetic forces of the magnet act on the iron filings and align them along the invisible magnetic field lines. The result is that the iron filings form a pattern similar to the magnetic field lines shown in the diagram in Figure 5.

Combined Magnetic Fields When the magnetic fields of two or more magnets overlap, the result is a combined field. Figure 6 shows the magnetic field produced when the poles of two bar magnets are brought near each other. Compare the combined field of two like poles to that of two unlike poles. Depending on which poles are near each other, the magnetic field lines are different. The fields from the like poles repel each other. But the fields from unlike poles attract each other. They combine to form a strong field between the two poles.

Reading Checkpoint **What happens when the magnetic fields of two or more magnets overlap?**

Differentiated Instruction

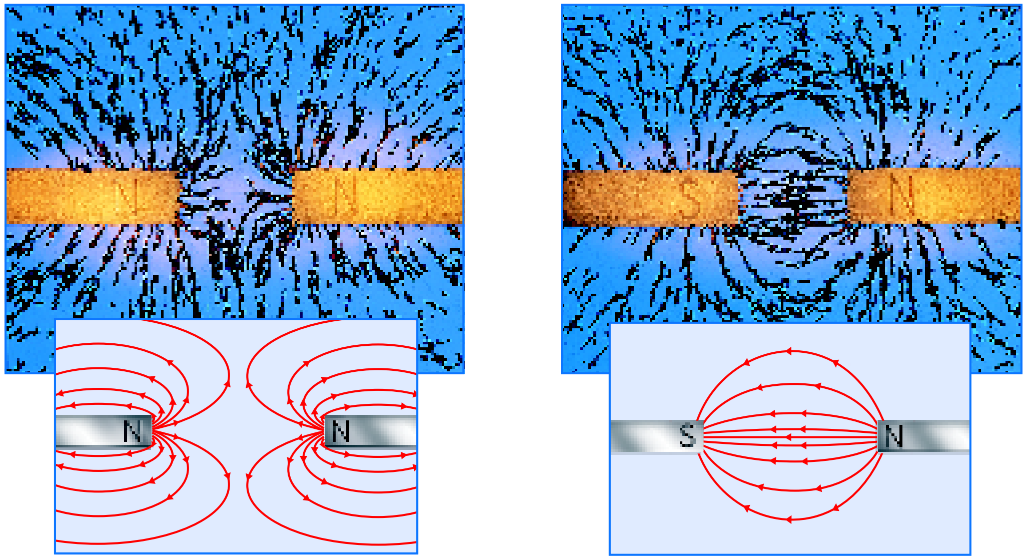
magnetic fields, distribute a rewritten, simplified version of the subsection Magnetic Fields. Then ask students simple questions that can be answered directly from the rewritten text. **learning modality: verbal**

English Learners/Intermediate L2
Comprehension: Ask Questions Have students read the simplified subsection you have prepared for the Beginning students, and then have them read the actual text again. Ask whether anything in the text subsection confused students, and help them clarify the meanings. **learning modality: verbal**

Monitor Progress L

Answers

FIGURE 6
Combined Magnetic Fields
The magnetic field of a single bar magnet is altered when another bar magnet is brought near it.



Section 1 Assessment

Target Reading Skill **Using Prior Knowledge** Review your graphic organizer and revise it based on what you just learned in the section.

Reviewing Key Concepts

1. a. **Reviewing** What is a magnet?
   b. **Summarizing** What are three properties of a magnet?
   c. **Predicting** What will happen to a bar magnet that is allowed to swing freely?
2. a. **Describing** What area of a magnet has the strongest magnetic effect?
   b. **Explaining** How does a magnet's north pole behave when brought near another north pole? Near a magnet's south pole?
   c. **Relating Cause and Effect** How can the behavior of two magnets show the presence of a magnetic force?
3. a. **Defining** What is a magnetic field?
   b. **Interpreting Diagrams** Look at Figure 4. What is the shape of the magnetic field?

Lab zone At-Home Activity

Magnetic Helpers Explain the properties of magnets to a member of your family. Then make a list of objects around your home that are most likely to contain or use one or more magnets. For example, magnets are used to hold some cabinet doors closed. Have your family member make a separate list. Compare the two lists and explain to your family member why each object is or is not likely to contain or use magnets.

Figure 5 The iron filings align along the magnetic field lines.

Reading Checkpoint The magnetic fields combine to form a stronger field between the magnets when unlike poles are near each other and a weaker field when like poles are near each other.

Assess

Reviewing Key Concepts

1. a. A magnet is any material that attracts iron and materials that contain iron. **b.** A magnet attracts materials that contain iron, attracts or repels other magnets, and has one pole that points north when allowed to swing freely. **c.** The bar magnet will align itself in a north-south direction.
2. a. A magnet's poles have the strongest magnetic effect. **b.** Two magnetic north poles repel each other. A magnetic north and a magnetic south pole attract each other. **c.** When unlike magnetic poles of two magnets are brought near one another, a force of attraction will tend to pull them together. When magnetic poles that are alike are brought near each other, a force of repulsion will tend to push them apart.
3. a. A magnetic field is the area of magnetic force around a magnet. **b.** Sample answer: The shape of a magnetic field resembles two side-by-side ovals, with the bar magnet lying along the long sides of the ovals where they contact each other.

Reteach L1

Have volunteers explain concepts related to magnets by using the photos in Figure 5 as reference. Ask students to describe properties of magnets, magnetic interactions, magnetic force, and magnetic fields.

Performance Assessment L2

Drawing Have students draw a bar magnet and label its poles. Then have students sketch the magnetic fields around the poles and indicate the alignment of the domains in the magnet.

All in One Teaching Resources
- Section Summary: *What Is Magnetism?*
- Review and Reinforcement: *What Is Magnetism?*
- Enrich: *What Is Magnetism?*

Magnetic Helpers L1 Students should compare their lists with the lists of their families. Recommend that students lead

Lab zone At-Home Activity

family discussions about whether or not objects contain or use magnets, basing their classifications on the objects' properties and uses. Ask students to compare their lists and share their findings with classmates.

Keep Students on Track By this point, groups should have tested a variety of objects and materials for

Lab zone Chapter Project

magnetic properties. If students do not already know how to make a temporary magnet, demonstrate this technique. Encourage groups to begin to plan a design for a magnetic sculpture.

Detecting Fake Coins

Lab zone **Skills Lab** L2

Prepare for Inquiry

Key Concept

U.S. coins are made from metals that are not magnetic, and thus they can be separated from magnetic metal slugs using a magnet.

Skills Objectives

After this lab, students will be able to:

- predict how different metals will react to the presence of a magnetic field
- observe how coins will slide straight down the cardboard and washers will be deflected and will slide along the stick
- develop hypotheses about the roles of the magnet and the stick in this lab

Prep Time 15 minutes
Class Time 40 minutes

Advance Planning

Collect the appropriate number of cardboard sheets, craft sticks, washers of various sizes, and small bar magnets. You will need the type of cardboard used to make file folders. Test the washers to make sure they are attracted to the magnets. Supply coins or have students bring their own.

All in One Teaching Resources

- Lab Worksheet: *Detecting Fake Coins*

Guide Inquiry

Invitation

Tell students that vending machines have to have a way of telling the difference between a real coin and a fake coin, often called a slug. Ask: **What are some characteristics of coins and slugs by which a vending machine could detect one from the other?** *(Students may list properties of coins, such as size, shape, mass, density, and magnetic properties.)*

Introduce the Procedure

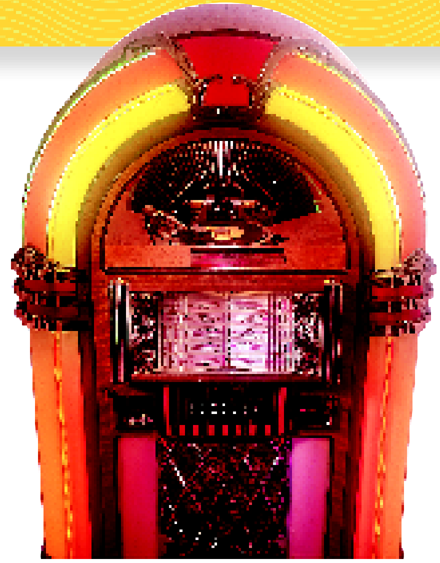
As students observe, place a pile of coins and washers mixed together on a desk. Move a magnet around the top of the pile and lift up the magnet. Students will observe that washers have stuck to the magnet, while the coins have been left behind.

Troubleshooting the Experiment

- One factor that can affect the effectiveness of students' devices is the angle of the inclined cardboard. When the angle is increased to more than 45°, the coins and washers will move down more quickly, decreasing a washer's chance of being attracted to the magnet.
- Another factor to consider is the strength of the magnet. If a strong magnet is used, a steeper angle of incline may be indicated. An alternative is to place the magnet farther than 1 centimeter from the center line.

Lab zone **Skills Lab**

Detecting Fake Coins



Problem

How can you use a magnet to tell the difference between real and fake coins?

Skills Focus

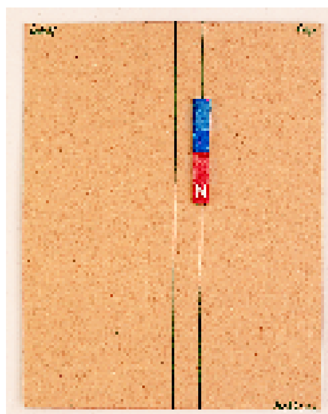
predicting, observing, developing hypotheses

Materials

- various coins
- craft stick
- tape
- metric ruler
- pencil
- protractor
- coin-size steel washers
- small bar magnet, about 2 cm wide
- thin, stiff cardboard, about 25 cm × 30 cm

Procedure

1. Use a pencil to label the front, back, top, and bottom of the piece of cardboard.
2. Draw a line lengthwise down the middle of both sides of the cardboard.
3. On the back of the cardboard, draw a line parallel to the first and about 2 cm to the right.
4. Place a magnet, aligned vertically, about a third of the way down the line you drew in Step 3. Tape the magnet in place.



5. Place a craft stick on the front of the card-board. The stick's upper end should be about 1 cm to the left of the center line and about 8 cm from the bottom of the cardboard.
6. Tape the stick at an angle, as shown in the photograph on the following page.
7. Prop the cardboard against something that will hold it at an angle of about 45°. Predict what will happen when you slide a coin down the front of the cardboard.
8. Place a coin on the center line and slide the coin down the front of the cardboard. (*Hint*: If the coin gets stuck, slowly increase the angle.)
9. Predict what will happen when you slide a steel washer.
10. Test your prediction by sliding a washer down the cardboard. Again, if the washer gets stuck, slowly increase the angle and try again.
11. Once you have reached an angle at which the objects slide easily, send down a ran-domly mixed group of coins and washers one at a time.

Analyze and Conclude

1. **Predicting** What was your prediction from Step 7? Explain your reasoning.
2. **Predicting** What was your prediction from Step 9? Explain your reasoning.
3. **Observing** Describe how observations made during the lab either supported or did not support your predictions.
4. **Developing Hypotheses** What is the role of the magnet in this lab?
5. **Developing Hypotheses** What is the role of the craft stick?
6. **Drawing Conclusions** What can you conclude about the metals from which the coins are made? About the metals in the washers?
7. **Controlling Variables** Why does the steepness of the cardboard affect how the coin-separating device works?
8. **Predicting** Some Canadian coins contain metals that are attracted to magnets. Would this device be useful in Canada to detect fake coins? Explain your answer.
9. **Communicating** Write a brochure that explains how the device could be used to separate real coins from fake coins and what advantages it might have for vending machine owners.

More to Explore

Go to a store that has vending machines. Find out who owns the vending machines. Ask the owners if they have a problem with counterfeit coins (sometimes called "slugs"). Ask how they or the makers of the vending machines solve the problem. How is their solution related to the device you built in this lab?

Expected Outcome Coins should slide straight down the center line on the cardboard and be deposited in a pile. Washers should be deflected to the side by the magnet and then slide down along the craft stick to be deposited in a separate pile.

Analyze and Conclude

1. Students' predictions will vary. Sample answer: The coins will slide straight down because they are not attracted by a magnet.

2. Sample answer: The washers will slide straight and then slide along the stick, because the magnet attracts washers.

3. Answers will depend on predictions. Sample answer: As predicted, the coins slid straight down the cardboard and the washers veered off and slid along the stick.

4. Sample answer: The magnet attracts any magnetic materials as they slide down the cardboard.

5. Sample answer: The craft stick serves to separate the two groups into piles at the bottom of the cardboard.

6. The coins are composed of nonmagnetic metals, which a magnet does not attract. The washers are composed of magnetic metals, which a magnet does attract.

7. The steepness of the cardboard affects the speed of objects sliding down. When objects are moving slowly, there is more chance that the magnet will attract objects made of magnetic materials.

8. The device would not be useful in Canada because some Canadian coins are magnetic and would be attracted by the magnet, just as fake coins are.

9. In their brochures, students should explain the difference between materials that are ferromagnetic and materials that are not. Students also describe how the device uses that difference to separate coins from slugs.

Extend Inquiry

More to Explore The device built in this lab is similar to the device used in many vending machines long ago. Today, magnetic fields are set up using electromagnets, and the size and mass of the coins are analyzed closely to differentiate real coins from fake coins.