Chapter 19 Magnetism

The BIG Idea

Properties of Matter

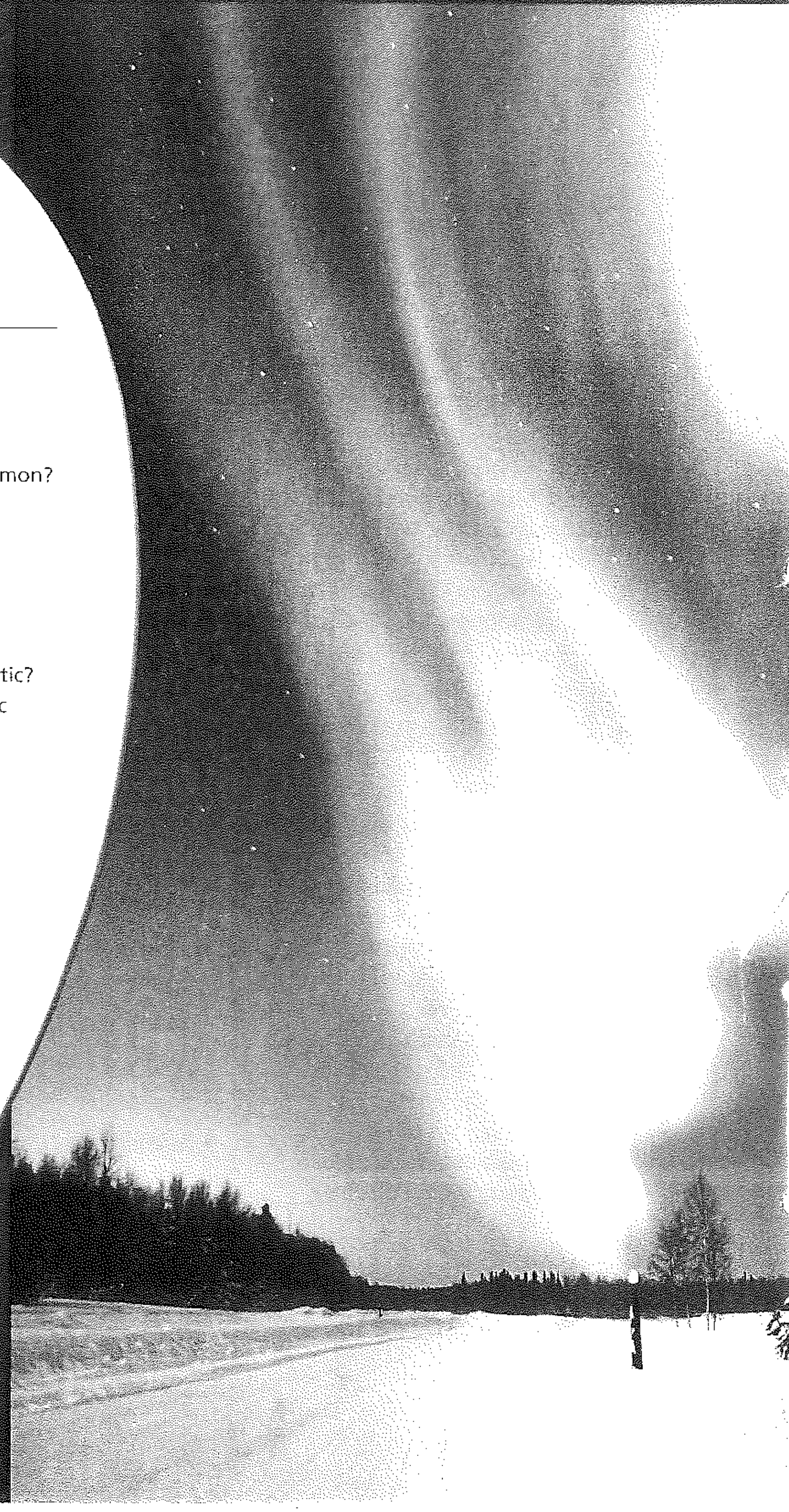
How do magnets interact?

Chapter Preview

1 What Is Magnetism?
Discover What Do All Magnets Have in Common?
Skills Activity Observing
Active Art Magnetic Field Lines
At-Home Activity Magnetic Helpers
Skills Lab Detecting Fake Coins

2 Inside a Magnet
Discover How Can Materials Become Magnetic?
Technology Lab Design and Build a Magnetic Paper Clip Holder

3 Magnetic Earth
Discover Can You Use a Needle to Make a Compass?
Analyzing Data Movement of Earth's Magnetic Poles
Skills Activity Measuring
Try This Spinning in Circles
At-Home Activity House Compass



The aurora borealis glows above a cabin in Manitoba, Canada.

Lab zone™ Chapter **Project**

Magnetic Art

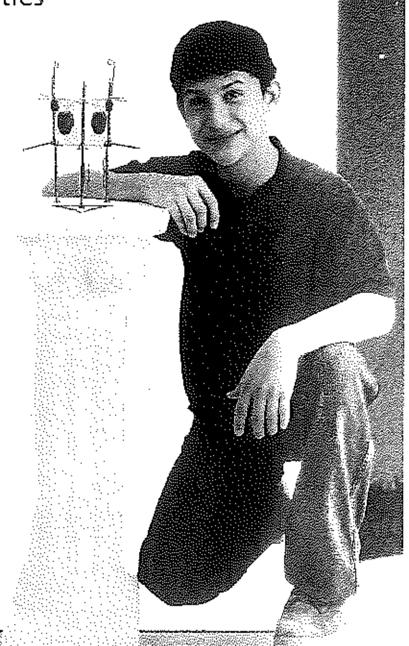
Magnetism is often used to do work, but it can also be used to create art! In this chapter project you will create a sculpture using nothing but magnetism to hold it together.

Your Goal To create a magnetic sculpture.

To complete this project, your sculpture must

- be held together *only* by magnets and objects with magnetic properties
- be at least 20 cm tall
- keep its shape for at least two hours
- follow the safety guidelines in Appendix A

Plan It! Your teacher will suggest a variety of materials that you can use to make your sculpture. With your group, brainstorm ideas for your plan. Decide which materials can be magnetized. After obtaining your teacher's approval for your plan, make your sculpture.



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.

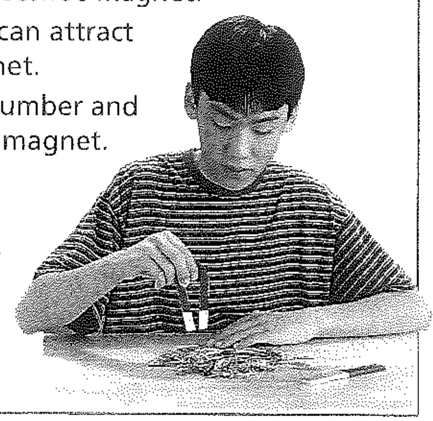
What You Know
1. Magnets stick to refrigerators.
2.

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.

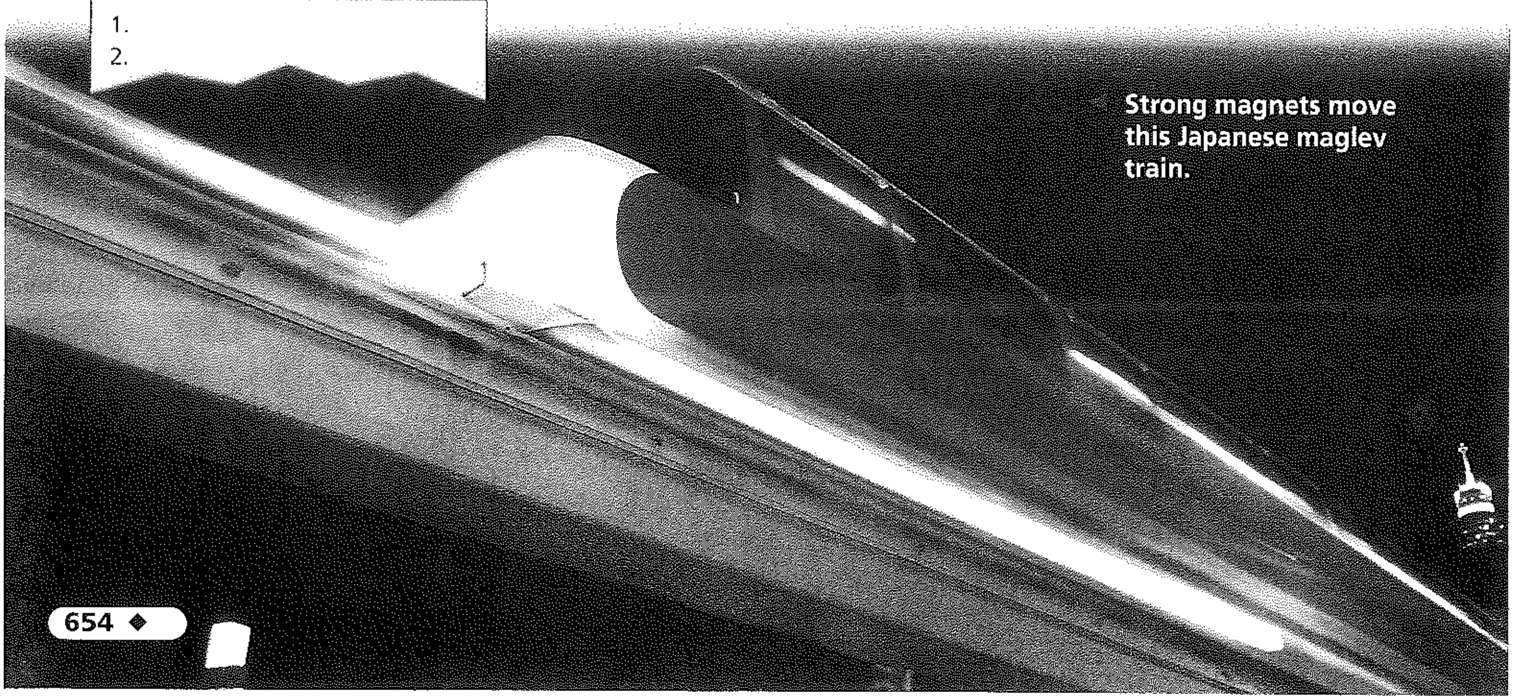


Think It Over

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.

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?**

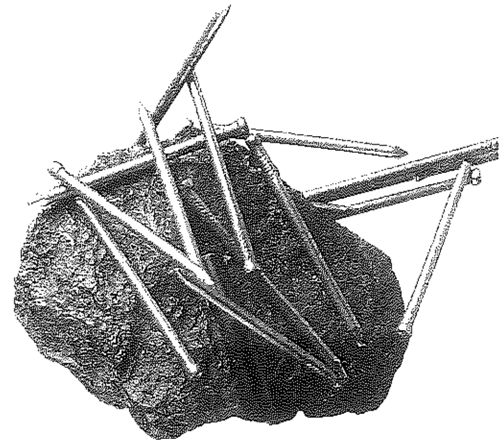


FIGURE 1
A Natural Magnet
Some magnets are found in nature. This rock attracts iron nails because it contains the magnetic mineral called magnetite.

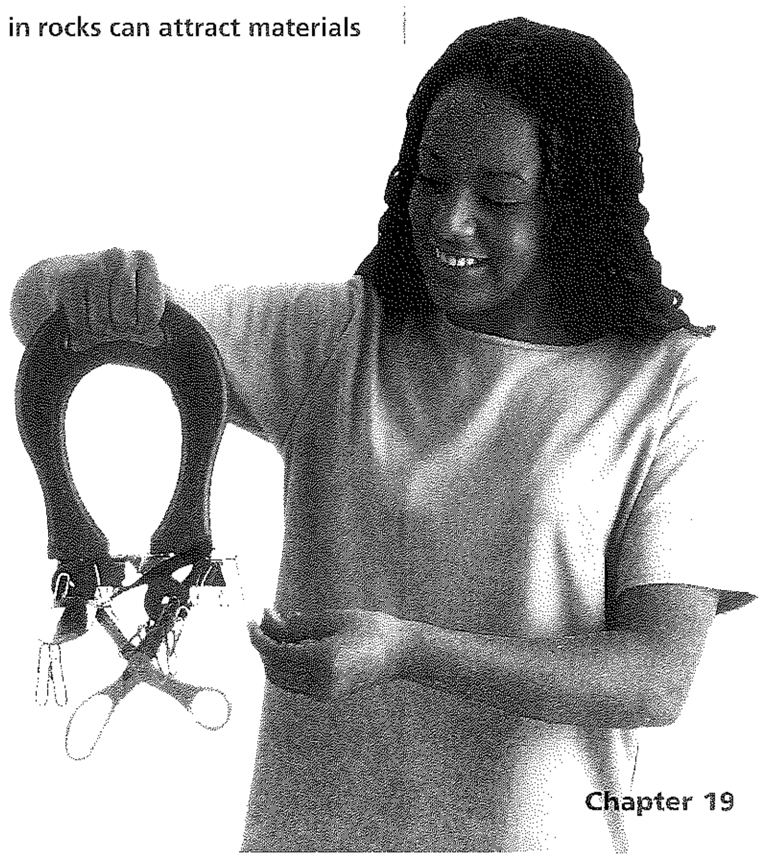


FIGURE 2
Modern Magnets
Magnets come in a variety of shapes and sizes, but they share certain characteristics. Inferring *What substance might the scissors, paper clips, and spoon have in common?*

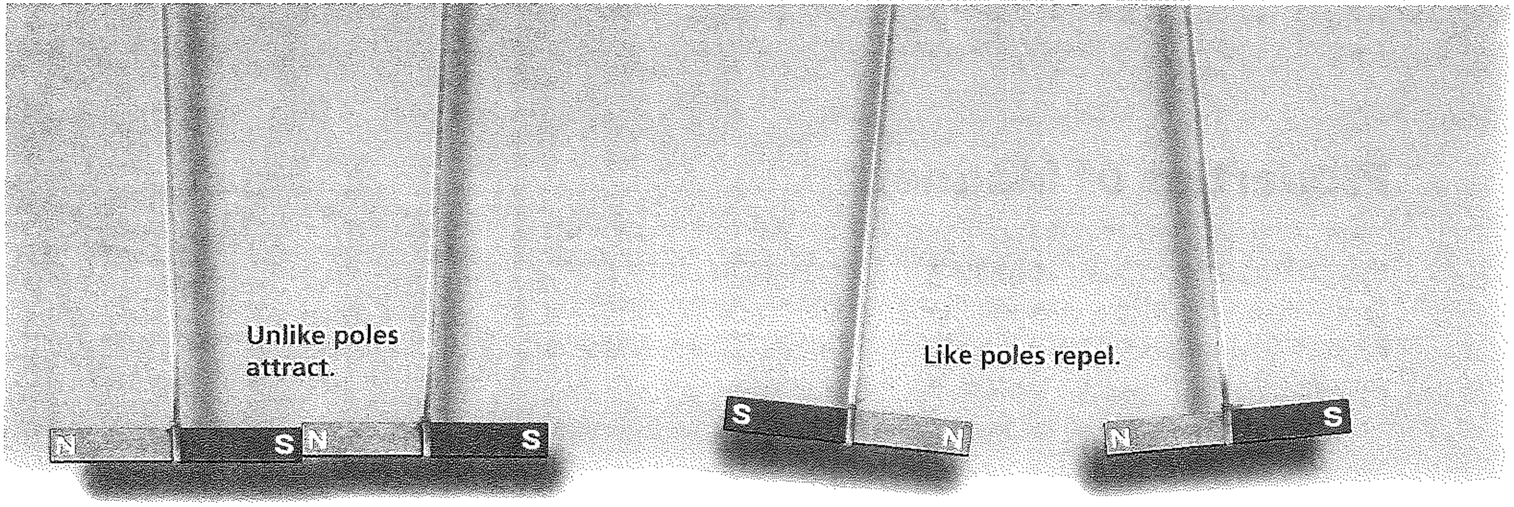


FIGURE 3
Attraction and Repulsion
Two bar magnets suspended by strings are brought near each other. Unlike poles attract each other; like poles repel each other.
Predicting *What would happen if two south poles were brought near one another?*

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.

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

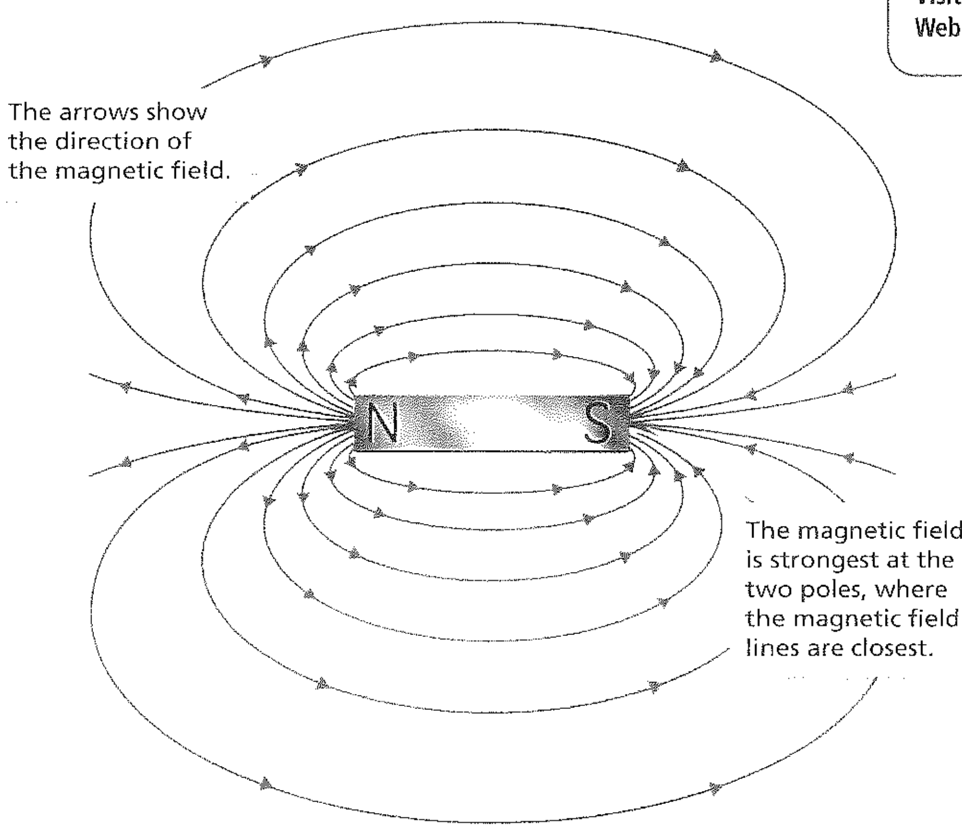


FIGURE 4
Magnetic Field Lines
A magnetic field surrounds a magnet. In this diagram, magnetic field lines are shown in red.

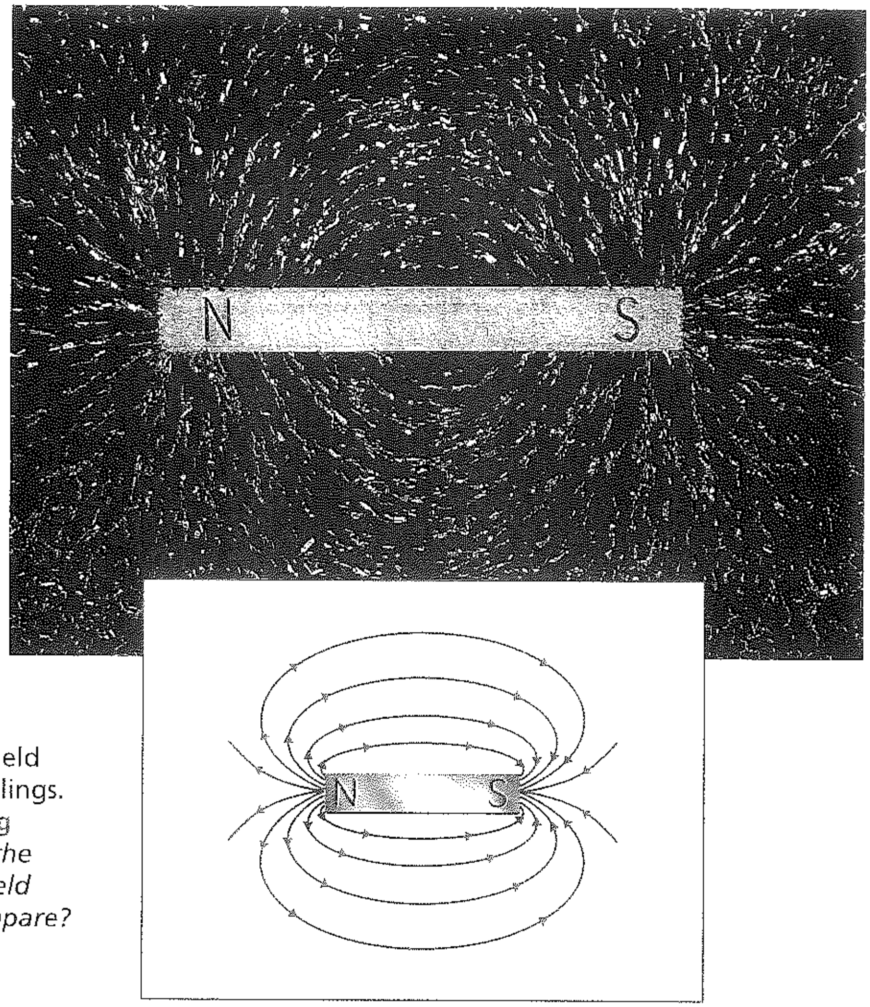


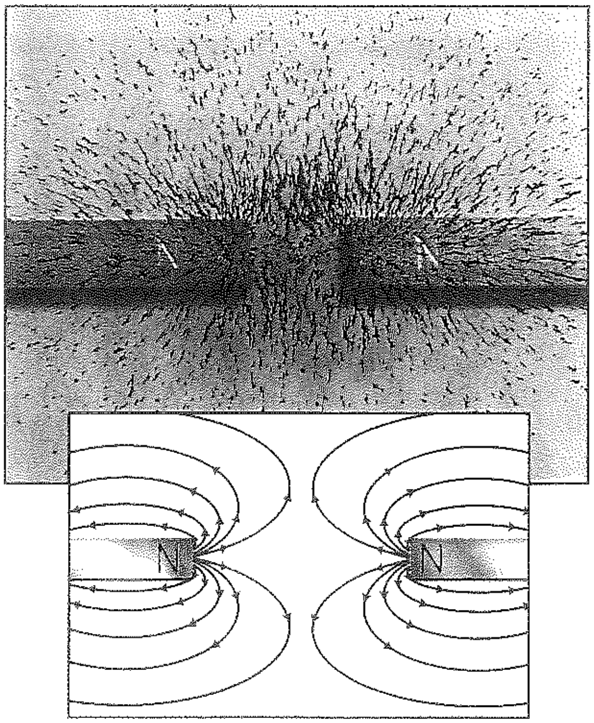
FIGURE 5
A Single Magnetic Field
A bar magnet's magnetic field is mapped out using iron filings.
Comparing and Contrasting
How do the iron filings in the photo and the magnetic field lines in the illustration compare?

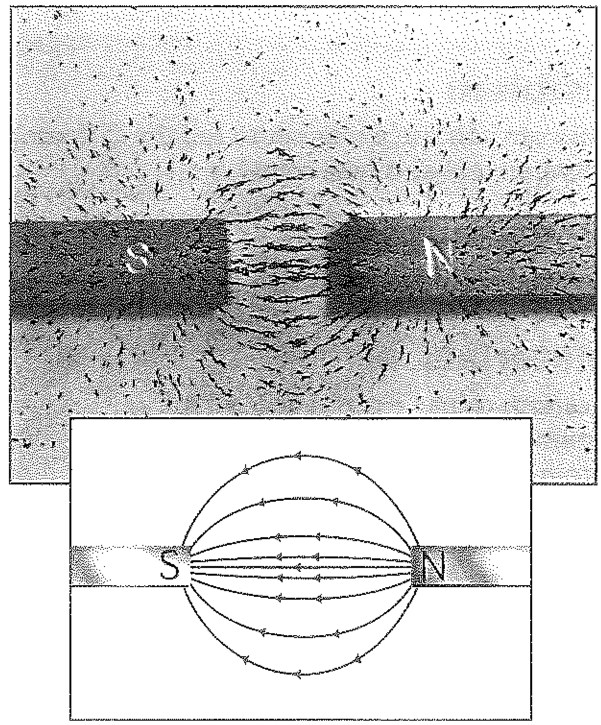
A Single Magnetic Field Although you cannot see a magnetic field, you can see its effects. The photograph in Figure 5 shows iron filings sprinkled on a sheet of plastic that covers one magnet. The magnetic forces of the magnet act on the iron filings and align them along the invisible magnetic field 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?**

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.

Lab zone **Skills Lab**

Detecting Fake Coins

Problem

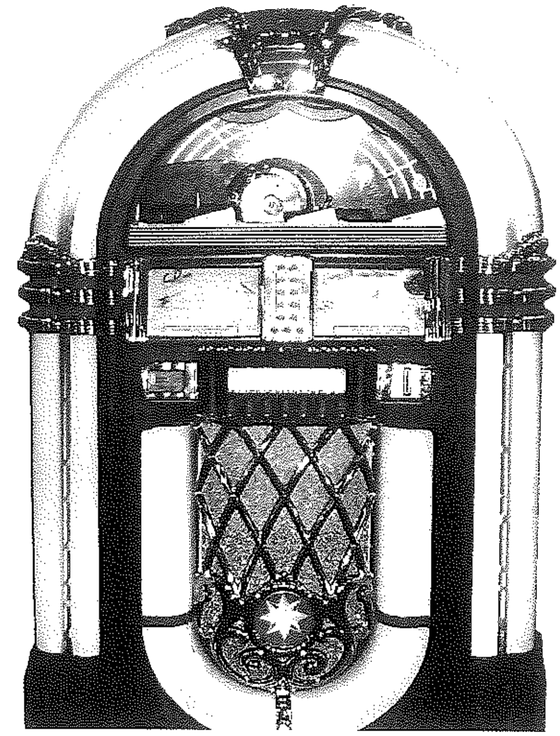
How can you use a magnet to tell the difference between real and fake coins?

Skills Focus

predicting, observing, developing hypotheses

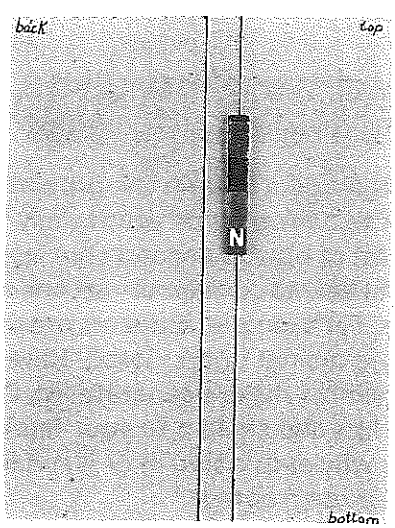
Materials

- 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.



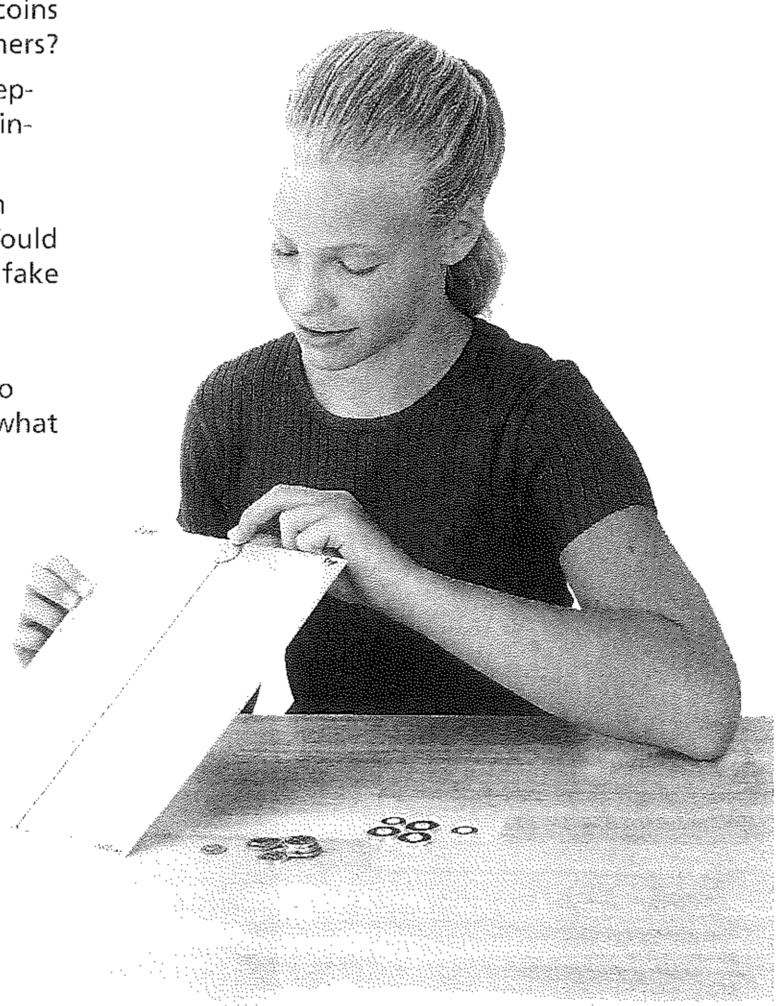
5. Place a craft stick on the front of the cardboard. The stick's upper end should be about 1 cm to the left of the center line and about 8 cm from the bottom of the cardboard.
6. Tape the stick at an angle, as shown in the photograph on the following page.
7. Prop the cardboard against something that 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 randomly 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?



Section 2

Inside a Magnet

Reading Preview

Key Concepts

- How can an atom behave like a magnet?
- How are magnetic domains arranged in a magnetic material?
- How can magnets be changed?

Key Terms

- atom • element • nucleus
- proton • neutron • electron
- magnetic domain
- ferromagnetic material
- temporary magnet
- permanent magnet

Target Reading Skill

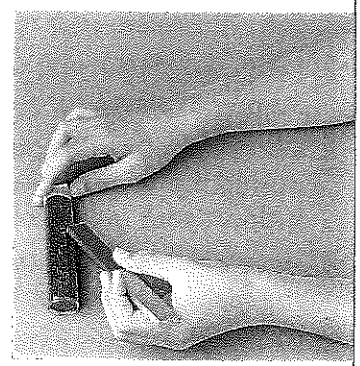
Asking Questions Before you read, preview the red headings. In a graphic organizer like the one below, ask a *what* or *how* question for each heading. As you read, write the answers to your questions.

Inside an Atom

Question	Answer
What are the three particles that make up an atom?	The three particles that make up an atom are . . .

Lab zone Discover Activity

How Can Materials Become Magnetic?

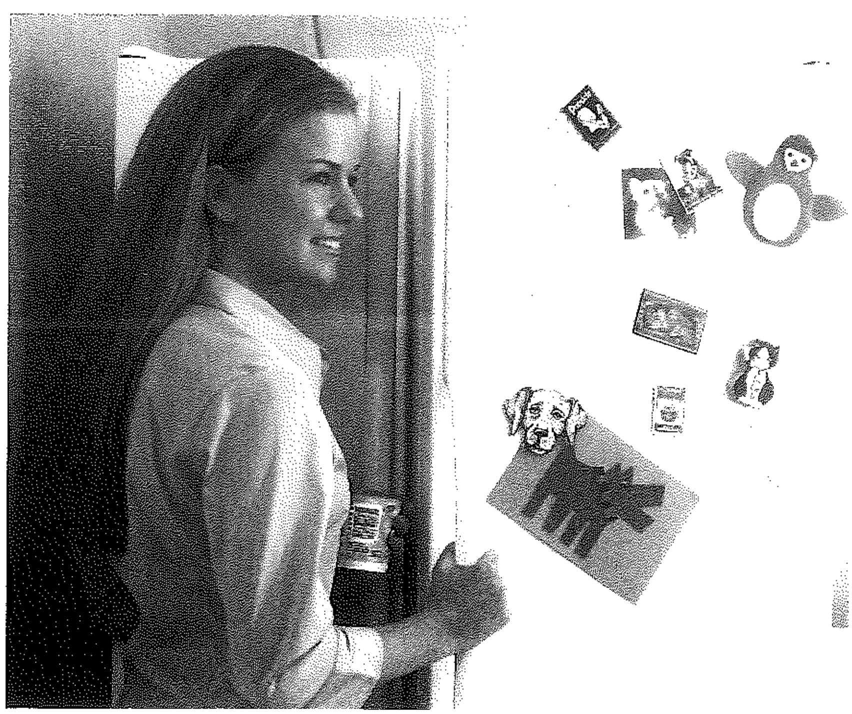


1. Fill a clear plastic tube about two-thirds full with iron filings.
2. Observe the arrangement of the filings.
3. Rub the tube lengthwise about 30 times in the same direction with one end of a strong magnet.
4. Again, observe the arrangement of the filings.

Think It Over

Drawing Conclusions What can you conclude from your observations?

You've probably noticed that if you bring a magnet near the door of your refrigerator, it clings. But what happens if you bring a piece of paper near the same refrigerator door? Nothing. You have to use a magnet to hold the paper against the door. Materials such as paper, plastic, rubber, and glass do not have magnetic properties. They will not cling to magnets and certain metals. Why are some materials magnetic while others are not?



Only certain materials will cling to the refrigerator using magnetism. ▶

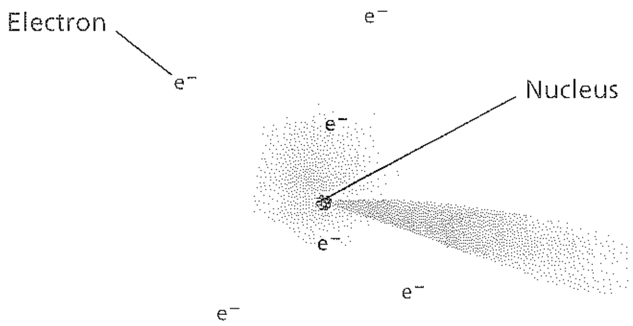
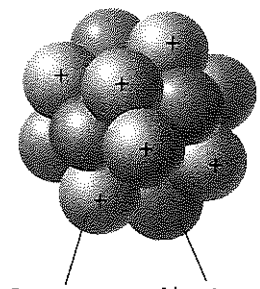


FIGURE 7
Structure of an Atom
An atom contains neutrons and positively charged protons in its nucleus. Negatively charged electrons move randomly throughout the atom.



The Atom

The magnetic properties of a material depend on the structure of its atoms. Because materials take up space and have mass, they are classified as matter. All matter is made up of atoms. An **atom** is the smallest particle of an element. An **element** is one of about 100 basic substances that make up all matter. The structure and composition of the atoms that make up a particular element make that element different from any other element.

Structure of an Atom Although atoms can differ, they have some characteristics in common. Every atom has a center region and an outer region. The center region of an atom is called a **nucleus.** Inside the nucleus two kinds of particles may be found: protons and neutrons. A **proton** is a particle that carries a positive charge. A **neutron** is a particle that does not carry a charge.

The outer region of an atom is mainly empty space. However, particles called electrons usually exist there. An **electron** is a particle that carries a negative charge. Electrons move randomly throughout the atom. They are much smaller than neutrons and protons. Look at Figure 7 to see the structure of an atom.

Electron Spin Each electron in an atom has a property called electron spin, so it behaves as if it were spinning. **A spinning electron produces a magnetic field that makes the electron behave like a tiny magnet in an atom.**

In most atoms, electrons form pairs that spin in opposite directions. Opposite spins produce opposite magnetic fields that cancel. Therefore, most atoms have weak magnetic properties. But some atoms contain electrons that are not paired. These atoms tend to have strong magnetic properties.

Reading Checkpoint **Why are most materials not magnetic?**

Magnetic Domains

The magnetic fields of the atoms in most materials point in random directions. The result is that the magnetic fields cancel one another almost entirely. The magnetic force is so weak that you cannot usually detect it.

In certain materials, however, the magnetic fields of many atoms are aligned with one another. A grouping of atoms that have their magnetic fields aligned is known as a **magnetic domain.** The entire domain acts like a bar magnet with a north pole and a south pole.

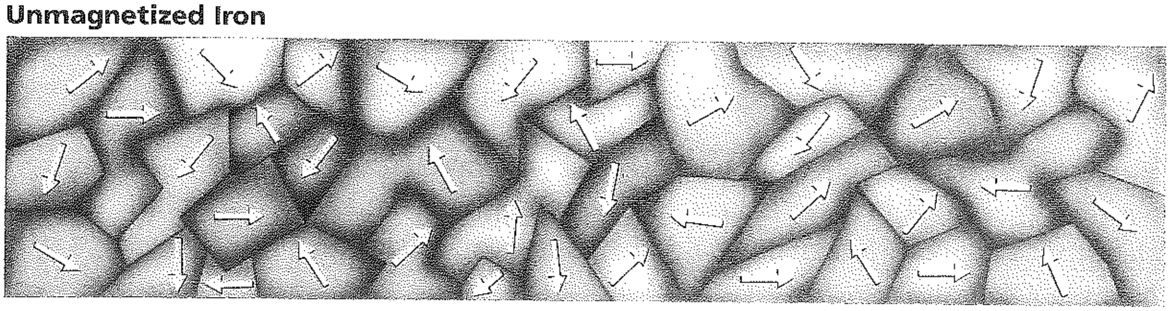
Alignment of Domains The direction in which the domains point determines if the material is magnetized or not magnetized. In a material that is not magnetized, the magnetic domains point in random directions, as shown in Figure 8. Therefore, the magnetic fields of some domains cancel the magnetic fields of other domains. The result is that the material is not a magnet.

Figure 8 has a diagram showing the arrangement of the domains in a magnetized material. You can see that most of the domains are pointing in the same direction. **In a magnetized material, all or most of the magnetic domains are arranged in the same direction.** In other words, the magnetic fields of the domains are aligned. If you did the Discover Activity at the beginning of this section you aligned the magnetic domains of the iron filings.

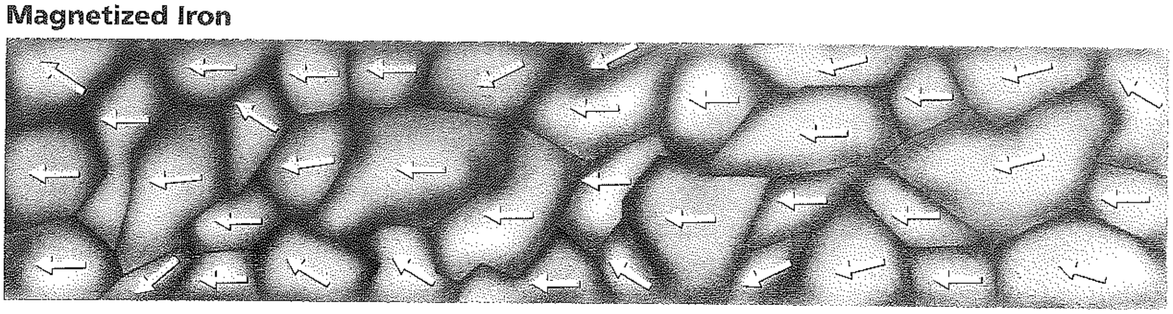
Reading Checkpoint **What is the arrangement of the magnetic domains in a material that is not magnetized?**

FIGURE 8
Magnetic Domains
The arrows represent the magnetic domains of a material. The arrows point toward the north pole of each magnetic domain.
Comparing and Contrasting *How does the arrangement of domains differ between magnetized iron and unmagnetized iron?*

Unmagnetized Iron



Magnetized Iron



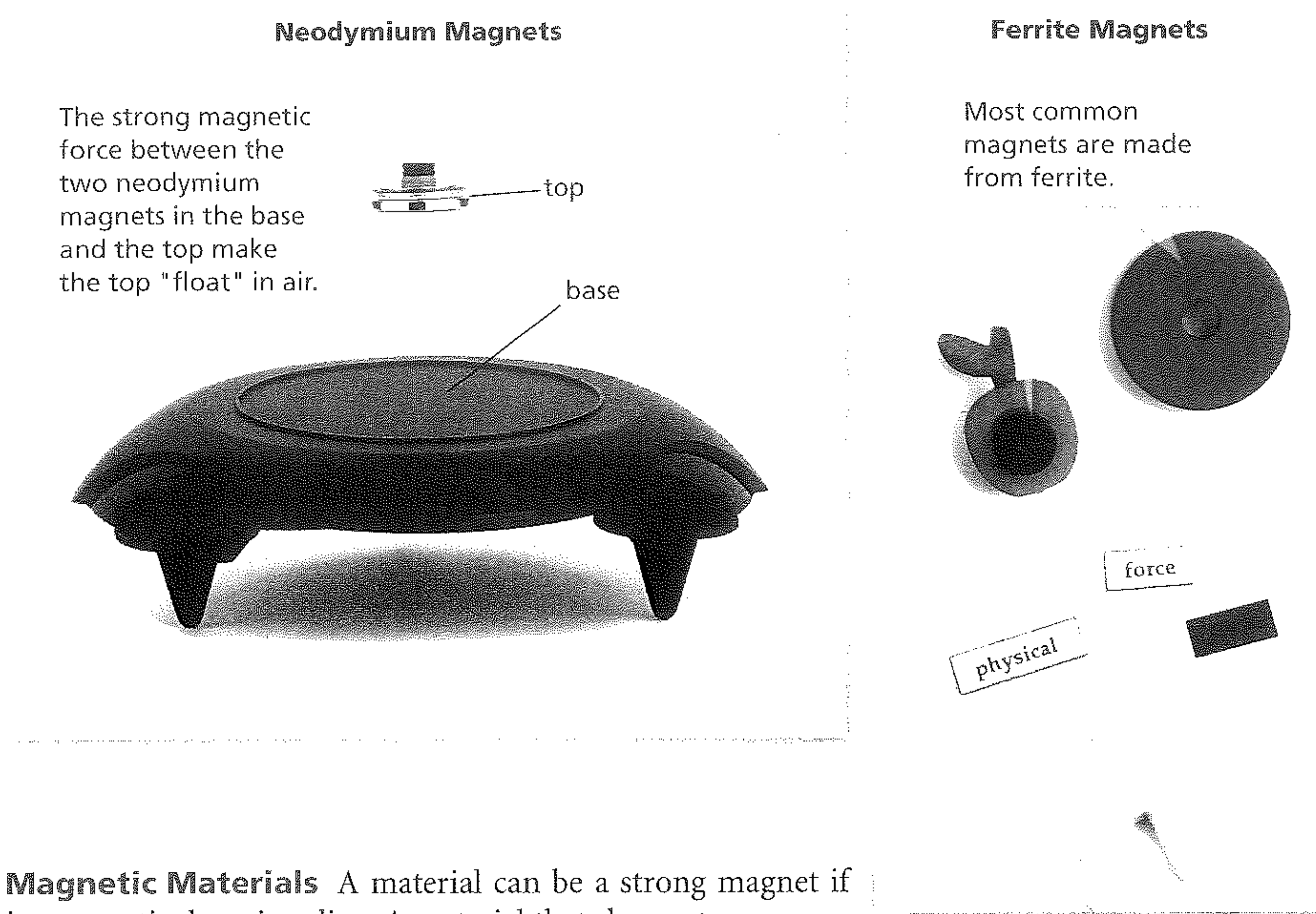


FIGURE 9
Magnets of Different Materials
Modern magnets come in a variety of shapes and are made from many different materials.

Magnetic Materials A material can be a strong magnet if its magnetic domains align. A material that shows strong magnetic properties is said to be a **ferromagnetic material.** The word *ferromagnetic* comes from the Latin *ferrum*, which means "iron." So a ferromagnetic material behaves like a piece of iron when it is placed in a magnetic field. In nature, iron, nickel, cobalt, and gadolinium are common ferromagnetic materials. Others include the rare elements samarium and neodymium, which can be made into extremely strong magnets as you can see in Figure 9.

Some magnets are made from several different metals. A combination of several metals is called an alloy. For example, the magnetic alloy alnico is made of aluminum, nickel, iron, and cobalt. Powerful magnets are also made of alloys of platinum and cobalt, and alloys of cobalt and neodymium.

Today, the most commonly used magnets are not made from alloys, but rather from a material called ferrite. Ferrite is a mixture of substances that contain ferromagnetic elements. Ferrite is a brittle material that chips easily, like some dishes. However, ferrite magnets are usually stronger and less expensive than metal magnets of similar size. Figure 9 shows some ferrite magnets.

Reading Checkpoint What are some common ferromagnetic materials found in nature?

Go Online SCILINKS NSTA
For: Links on magnetic materials
Visit: www.SciLinks.org
Web Code: scn-1412

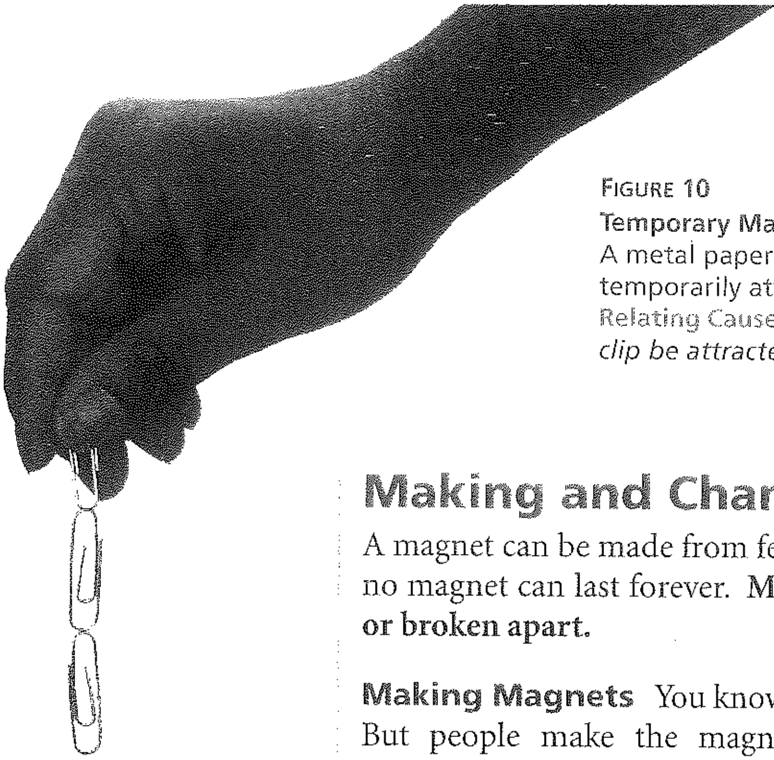


FIGURE 10
Temporary Magnets
A metal paper clip can be magnetized and temporarily attract another paper clip.
Relating Cause and Effect *How can a paper clip be attracted to another paper clip?*

Making and Changing Magnets

A magnet can be made from ferromagnetic material. However, no magnet can last forever. **Magnets can be made, destroyed, or broken apart.**

Making Magnets You know that magnetite exists in nature. But people make the magnets you use every day. Some unmagnetized materials can be magnetized. A magnet can be made by placing an unmagnetized ferromagnetic material in a strong magnetic field or by rubbing the material with one pole of a magnet.

Suppose, for example, that you want to magnetize a steel paper clip. Steel contains iron. So you can magnetize the paper clip by rubbing in one direction with one pole of a magnet. The magnetic field of the magnet causes some domains in the paper clip to line up in the same direction as the domains in the magnet. The more domains that line up, the more magnetized the paper clip becomes.

Some materials, such as the steel in a paper clip or pure iron, are easy to magnetize, but lose their magnetism quickly. A magnet made from a material that easily loses its magnetism is called a **temporary magnet**. Other materials, such as those in strong magnets, are hard to magnetize, but tend to stay magnetized. A magnet made from a material that keeps its magnetism for a long time is called a **permanent magnet**.

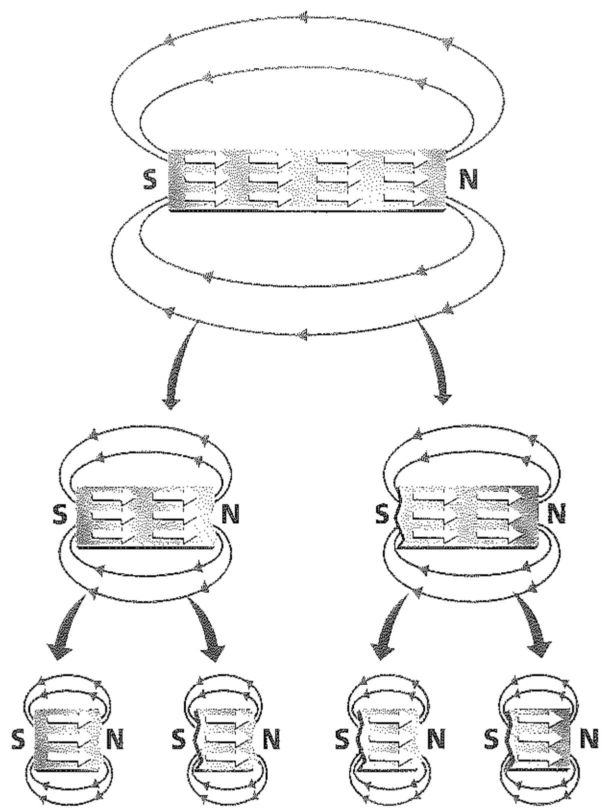
Destroying Magnets Like a temporary magnet, a permanent magnet can also become unmagnetized. One way for a magnet to become unmagnetized is to drop it or strike it hard. If a magnet is hit hard, its domains can be knocked out of alignment. Heating a magnet will also destroy its magnetism. When an object is heated, its particles vibrate faster and more randomly. These movements make it more difficult for all the domains to stay lined up. Above a certain temperature, every ferromagnetic material loses its magnetic properties. The temperature depends on the material.

Breaking Magnets What happens if you break a magnet in two? Do you have a north pole in one hand and a south pole in the other? The answer is no—you have two smaller magnets. Each smaller magnet has its own north pole and south pole. If you break those two halves again, you have four magnets.

Now that you know about domains, you can understand why breaking a magnet in half does not result in two pieces that are individual poles. Within the original magnet shown in Figure 11, many north and south poles are facing each other. Many of the magnet's domains are lined up in one direction. This produces a strong magnetic force at the magnet's north and south poles. If the magnet is cut in half, the domains in the two halves will still be lined up in the same way. So the shorter pieces will still have strong ends made up of many north or south poles.

Reading Checkpoint **What is a temporary magnet?**

FIGURE 11
Magnet Pieces
Each piece of a magnet retains its magnetic properties after it is cut in half.



Section 2 Assessment

Target Reading Skill Asking Questions Work with a partner to check the answers in your graphic organizer.

Reviewing Key Concepts

1. a. Listing What particles are found in an atom?
   b. Identifying Which particle is responsible for a material's magnetic properties?
   c. Relating Cause and Effect How is a magnetic field produced in an atom?
2. a. Defining What is a magnetic domain?
   b. Explaining How are domains arranged in materials that are magnetized and in ones that are not?
   c. Applying Concepts What happens to the domains in iron filings that line up with the magnetic field of a bar magnet?
3. a. Reviewing How can magnets be changed?
   b. Comparing and Contrasting How are temporary and permanent magnets alike? How are they different?

Writing in Science

Writing Dialogue You are discussing magnets with another person. That person thinks that breaking a magnet will destroy the magnet's magnetic properties. Write a conversation you might have with the other person as you try to explain why the person's idea is incorrect.

Lab zone **Technology Lab**

• Tech & Design •

Design and Build a Magnetic Paper Clip Holder

Problem

Many objects that you use in your daily life contain magnets. Can you design and build a magnetic paper clip holder?

Skills Focus

designing the solution, evaluating the design, troubleshooting

Materials

- 2 bar magnets
- masking tape
- container of 150 regular size paper clips
- an assortment of types, shapes, and sizes of magnets, including two bar magnets
- modeling clay, string, and other materials approved by your teacher

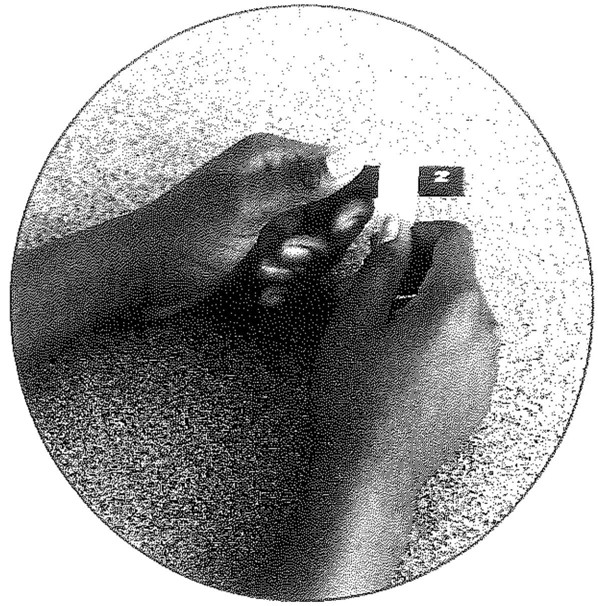
Procedure

PART 1 Research and Investigate

1. Copy the data table into your notebook.
2. Place one pole of a bar magnet into a container of paper clips. Slowly lift the magnet and count how many paper clips are attached to it. Record the number of paper clips in your data table. Return the paper clips to the container.
3. Repeat Step 2 two more times.
4. Calculate the average number of paper clips you lifted in the three trials.

Data Table

Type of magnet	Number of paper clips



5. Use the other pole of the bar magnet and repeat Step 2.
6. Repeat Step 2 again using the poles of each of the other magnets to pick up the paper clips.
7. Repeat Step 2 using 3 or 4 different combinations of magnets. For example, you can tape two magnets together, as shown in the photo.

PART 2 Design and Build

8. Examine your data. Use it to design a magnetic paper clip holder that
   - holds at least 150 paper clips
   - allows easy access to the paper clips (*Hint:* The holder could sit on a desk or hang suspended from an object)
   - is made of materials approved by your teacher
   - is built following the Safety Guidelines in Appendix A
9. Draw a sketch of your paper clip holder and include a list of materials you'll need. Obtain your teacher's approval of your design. Then build your holder.

PART 3 Evaluate and Redesign

10. Test your holder. Does the device meet the criteria listed in Step 8? Compare the design and performance of your holder with the holders of some of your classmates.
11. Based on what you learned, redesign your holder. After you receive your teacher's approval, build and test your redesigned holder.

Analyze and Conclude

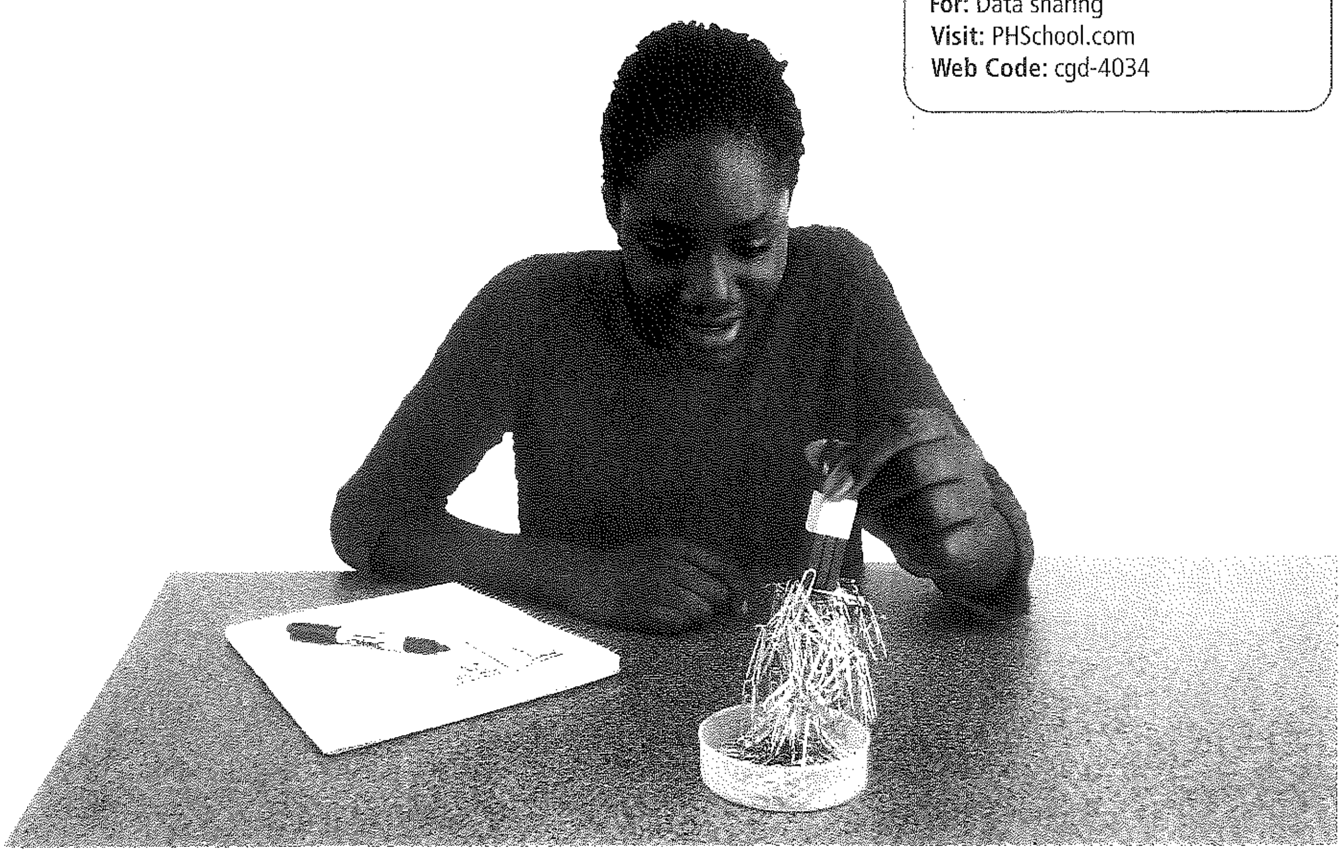
1. Inferring Why did you test each magnet three times in Part 1?
2. Drawing Conclusions What conclusions did you draw from the data you collected in Part 1?
3. Designing a Solution How did you use the data you collected to design your paper clip holder?
4. Troubleshooting Describe one problem you faced while designing or building your holder. How did you solve the problem?
5. Working With Design Constraints What limitations did the criteria of holding at least 150 paper clips place on your design? How did you solve those limitations?
6. Evaluating the Impact on Society Describe how a device that uses magnets affects your life on a daily basis.

Communicate

Write a letter to a friend that describes how you combined magnets to build a practical paper clip holder.

Go Online
PHSchool.com

For: Data sharing
Visit: PHSchool.com
Web Code: cgd-4034



Magnetic Earth

Reading Preview

Key Concepts

- How is Earth like a bar magnet?
- What are the effects of Earth's magnetic field?

Key Terms

- compass
- magnetic declination
- Van Allen belts
- solar wind
- magnetosphere
- aurora

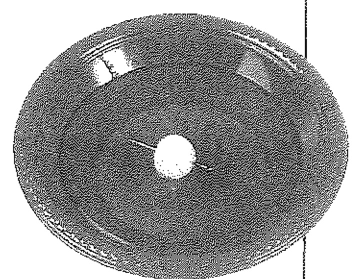
Target Reading Skill

Building Vocabulary Using a word in a sentence helps you think about how best to explain the word. After you read the section, reread the paragraphs that contain definitions of Key Terms. Use all the information you have learned to write a meaningful sentence using the Key Term.

Lab zone Discover Activity

Can You Use a Needle to Make a Compass?

1. Magnetize a large needle by rubbing it several times in the same direction with one end of a strong bar magnet. Push the needle through a ball of foam or tape it to a small piece of cork.
2. Place a drop of dishwashing soap in a bowl of water. Then float the foam or cork in the water. Adjust the needle until it floats horizontally.
3. Allow the needle to stop moving. Note the direction it points.
4. Use a local map to determine the direction in which it points.

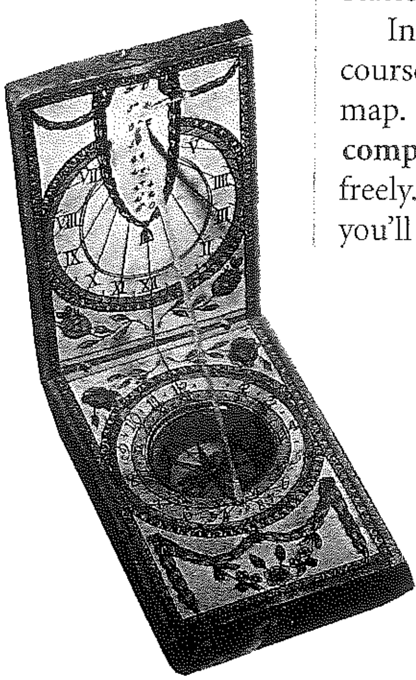


Think It Over

Observing In what direction did the needle point? If you repeat the activity, will it still point in the same direction? What does this tell you about Earth?

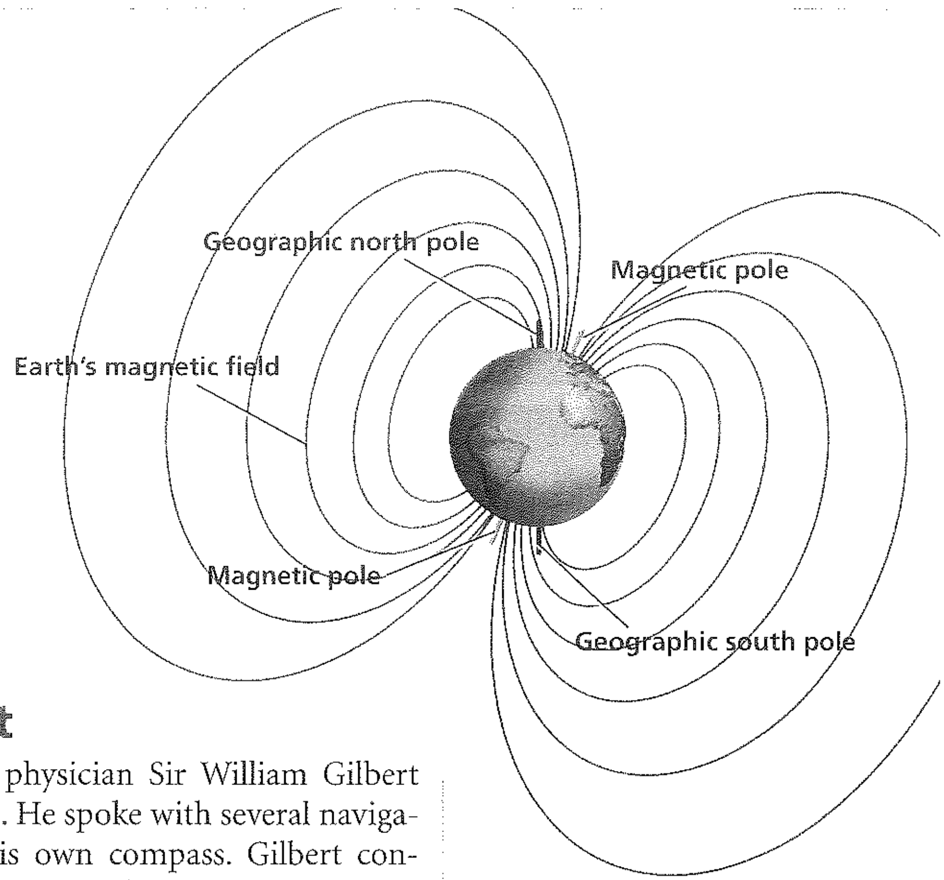
When Christopher Columbus sighted land in 1492, he didn't know what he had found. He was trying to find a shortcut from Europe to India. Where he landed, however, was on an island in the Caribbean Sea just south of the present-day United States. He had no idea that such an island even existed.

In spite of his error, Columbus had successfully followed a course west to the Americas without the help of an accurate map. Instead, Columbus used a compass for navigation. A **compass** is a device that has a magnetized needle that spins freely. A compass needle usually points north. As you read, you'll find out why.



◄ Columbus navigated across the Atlantic Ocean using a compass similar to this one.

FIGURE 12
Earth's Magnetic Field
The magnetic field lines show the shape of Earth's magnetic field.
Observing *What magnetic properties does Earth have?*



Earth as a Magnet

In the late 1500s, the English physician Sir William Gilbert became interested in compasses. He spoke with several navigators and experimented with his own compass. Gilbert confirmed that a compass always points in the same direction, no matter where it is. But no one knew why.

Gilbert hypothesized that a compass behaves as it does because Earth acts as a giant magnet. Although many educated people of his time laughed at this idea, Gilbert turned out to be correct. **Just like a bar magnet, Earth has a magnetic field surrounding it and two magnetic poles.**

The fact that Earth has a magnetic field explains why a compass works as it does. The poles of the magnetized needle on the compass align themselves with Earth's magnetic field.

Earth's Core Gilbert thought that Earth's center, or core, contains magnetic rock. Scientists now think that this is not the case, since the material inside Earth's core is too hot to be solid. Also, the temperature is too high for the material to be magnetic. Earth's magnetism is still not completely understood. But scientists do know that the circulation of molten material in Earth's core is related to Earth's magnetism.

Earth's Magnetic Poles You know that Earth rotates on its axis, around the geographic poles. But Earth also has magnetic poles. These magnetic poles are located on Earth's surface where the magnetic force is strongest. As you can see in Figure 12, the magnetic poles are not in the same place as the geographic poles. For example, the magnetic pole in the Northern Hemisphere is located in northern Canada about 1,250 kilometers from the geographic North Pole.

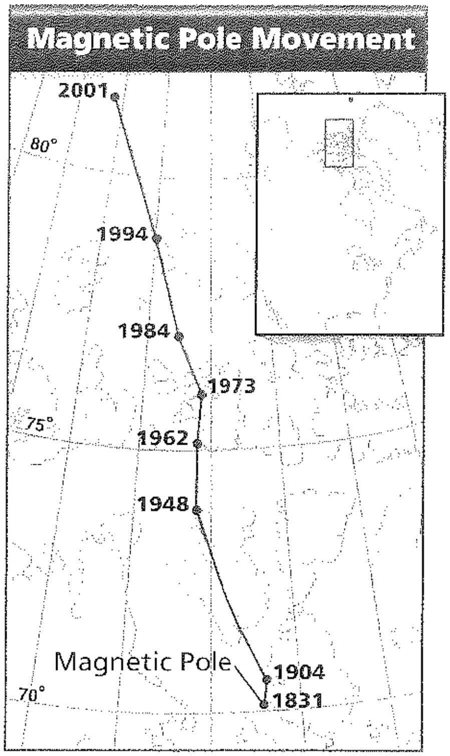


FIGURE 13
The location of Earth's magnetic poles does not stay the same.

Magnetic Declination If you use a compass, you have to account for the fact that Earth's geographic and magnetic poles are different. Suppose you could draw a line between you and the geographic North Pole. The direction of this line is geographic north. Then imagine a second line drawn between you and the magnetic pole in the Northern Hemisphere. The angle between these two lines is the angle between geographic north and the north to which a compass needle points. This angle is known as **magnetic declination.** So, magnetic declination differs depending on your location on Earth.

The magnetic declination of a location on Earth today is not the same as it was 10 years ago. The magnetic declination of a location changes. Earth's magnetic poles do not stay in one place as the geographic poles do. Figure 13 shows how the location of Earth's magnetic pole in the Northern Hemisphere has drifted over time.

Earth's Magnetic Field

You learned that a material such as iron can be made into a magnet by a strong magnetic field. **Since Earth produces a strong magnetic field, Earth itself can make magnets out of ferromagnetic materials.**

Earth as a Magnet Maker Suppose you leave an iron bar lying in a north-south direction for many years. Earth's magnetic field may attract the domains strongly enough to cause them to line up in the same direction. When the domains in the iron bar align, the bar becomes a magnet. This can happen to some everyday objects. So even though no one has tried to make metal objects such as file cabinets in your school into magnets, Earth might have done so anyway!

Math Analyzing Data

Movement of Earth's Magnetic Poles

Earth's magnetic poles move slowly over time. The data in the table show the position of Earth's magnetic north pole in specific years.

1. Interpreting Data What is the trend in the speed of the pole's movement?
2. Calculating What is the total distance the pole has traveled over the time shown?
3. Predicting Using this data, predict the average speed of the pole's movement between 2001 and 2010. Explain.

Magnetic North Pole Movement

Year of Reading	Distance Moved Since Previous Reading (km)	Average Speed (km/yr)
1948	420	9.5
1962	150	10.7
1973	120	10.9
1984	120	10.9
1994	180	18.0
2001	287	41.0

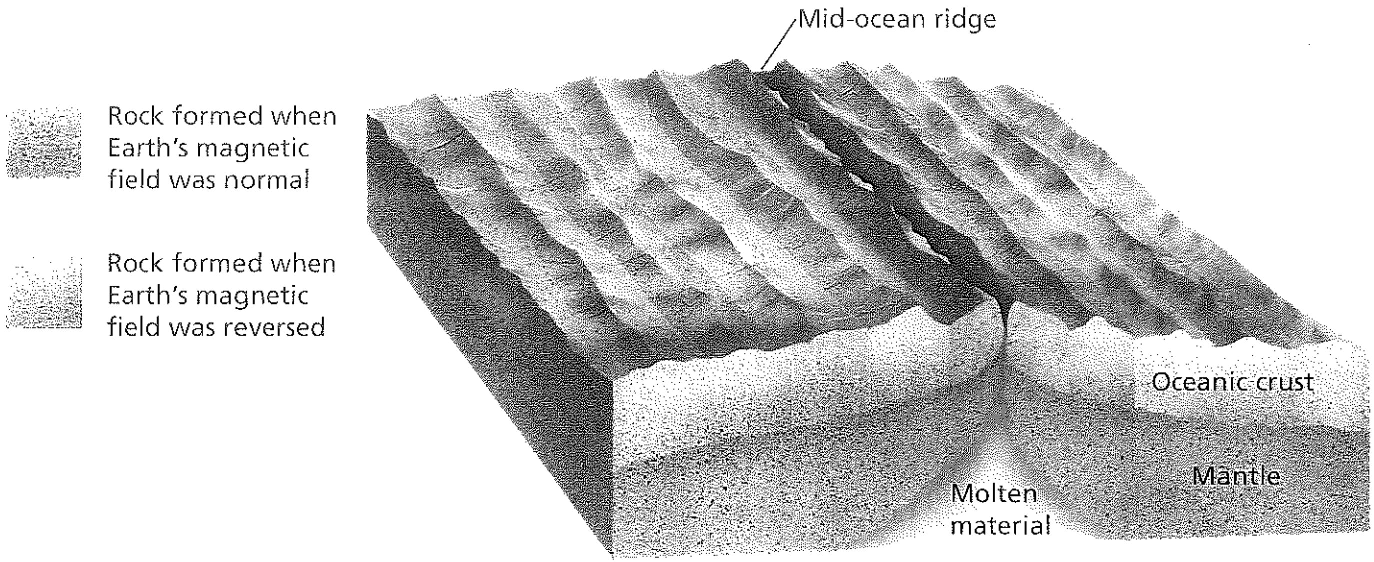


FIGURE 14
Earth's Magnetic Stripes
When molten material hardens into the rock of the ocean floor, the direction of Earth's magnetic field at that time is permanently recorded. **Applying Concepts** *How can scientists use this rock record to study changes in Earth's magnetic field?*

Earth Leaves a Record Earth's magnetic field also acts on rocks that contain magnetic material, such as rock on the ocean floor. Rock is produced on the ocean floor from molten material that seeps up through a long crack in the ocean floor known as a mid-ocean ridge. When the rock is molten, the iron it contains lines up in the direction of Earth's magnetic field. As the rock cools and hardens, the iron is locked in place. This creates a permanent record of the magnetic field.

As scientists studied such rock, they discovered that the direction and strength of Earth's magnetic field have changed over time. Earth's magnetic field has completely reversed direction every million years or so.

The different colored layers in Figure 14 indicate the directions of Earth's magnetic field over time. Notice that the patterns of bands on either side of the ridge are mirror images. This is because the sea floor spreads apart from the mid-ocean ridge. So rocks farther from the ridge are older than rocks near the ridge. Scientists can determine when the rock was formed by looking at the rock's magnetic record.

Why does Earth's magnetic field change direction? No one knows. Scientists hypothesize that changes in the motion of molten material in Earth's core may cause changes in Earth's magnetic field. But scientists cannot explain why changes in the molten material take place.

Reading Checkpoint **What evidence shows that Earth's magnetic field changes?**

Lab zone Skills Activity

Measuring

1. Use a local map to locate geographic north relative to your school. Mark the direction on the floor with tape or chalk.
2. Use a compass to find magnetic north. Again mark the direction.
3. Use a protractor to measure the number of degrees between the two marks.

Compare the directions of magnetic and geographic north. Is magnetic north to the east or west of geographic north?

Lab zone Try This Activity

Spinning in Circles

Which way will a compass point?

1. Place a bar magnet in the center of a sheet of paper.
2. Place a compass about 2 cm beyond the north pole of the magnet. Draw a small arrow showing the direction of the compass needle.
3. Repeat Step 2, placing the compass at 20 to 30 different positions around the magnet.
4. Remove the magnet and observe the pattern of arrows you drew.

Drawing Conclusions What does your pattern of arrows represent? Do compasses respond only to Earth's magnetic field?

The Magnetosphere

Earth's magnetic field extends into space. Space is not empty. It contains electrically charged particles. **Earth's magnetic field affects the movements of electrically charged particles in space.** Those charged particles also affect Earth's magnetic field.

Between 1,000 and 25,000 kilometers above Earth's surface are two doughnut-shaped regions called the **Van Allen belts.** They are named after their discoverer, J. A. Van Allen. These regions contain electrons and protons traveling at very high speeds. At one time it was feared that these particles would be dangerous for spacecraft passing through them, but this has not been the case.

Solar Wind Other electrically charged particles in space come from the sun. Earth and the other objects in our solar system experience a solar wind. The **solar wind** is a stream of electrically charged particles flowing at high speeds from the sun. The solar wind pushes against Earth's magnetic field and surrounds the field, as shown in Figure 15. The region of Earth's magnetic field shaped by the solar wind is called the **magnetosphere.** The solar wind constantly reshapes the magnetosphere as Earth rotates on its axis.

Although most particles in the solar wind cannot penetrate Earth's magnetic field, some particles do. They follow Earth's magnetic field lines to the magnetic poles. At the poles, the magnetic field lines dip down to Earth's surface.

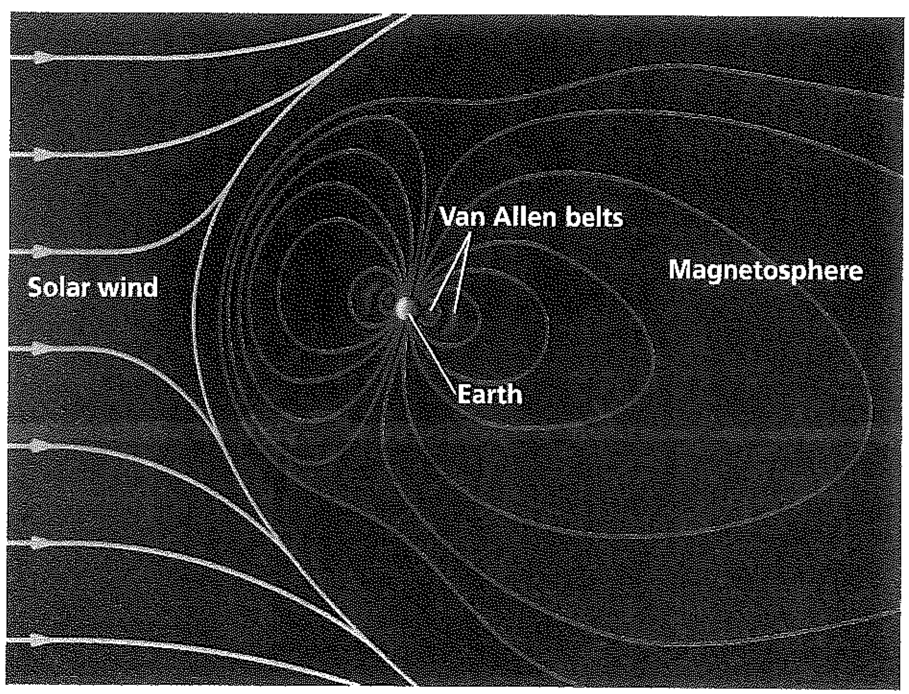


FIGURE 15
Earth's Magnetosphere
The solar wind causes Earth's magnetic field to stretch out on the side of Earth not facing the sun.
Relating Cause and Effect *What shapes the magnetosphere?*

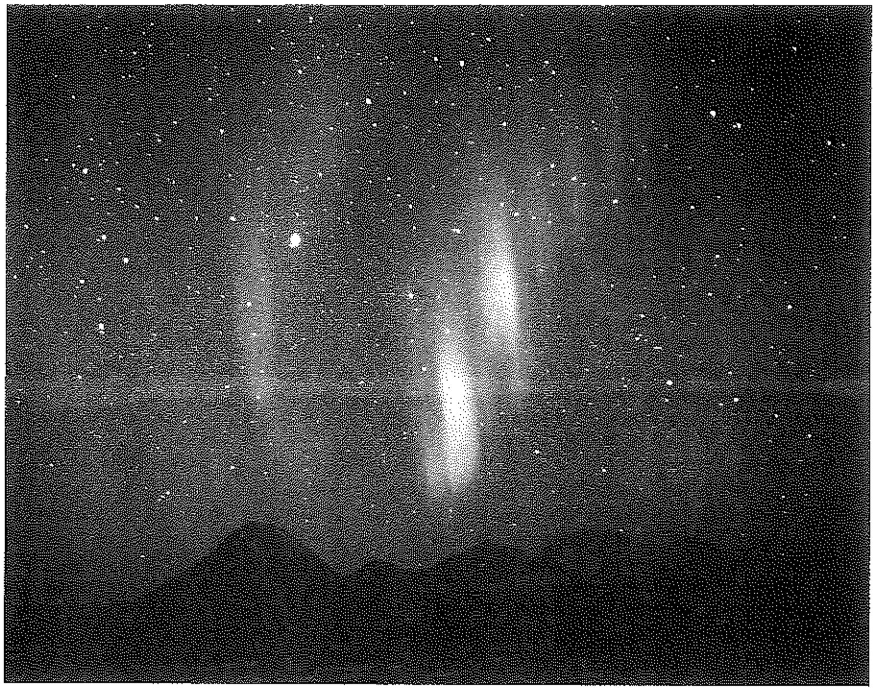


FIGURE 16
Aurora
A band of colored light called an aurora occasionally appears in the night sky near the magnetic poles.

Auroras When high-speed, charged particles get close to Earth's surface, they interact with atoms in the atmosphere. This causes some of the atoms to give off light. The result is one of Earth's most spectacular displays—a curtain of shimmering bright light in the atmosphere. A glowing region in the atmosphere caused by charged particles from the sun is called an **aurora**. In the Northern Hemisphere, an aurora is called the Northern Lights, or aurora borealis. In the Southern Hemisphere, it is called the Southern Lights, or aurora australis.

Reading Checkpoint **What causes an aurora?**

Go Online — PHSchool.com
For: More on Earth's magnetic field
Visit: PHSchool.com
Web Code: cgd-4013

Section 3 Assessment

Target Reading Skill Building Vocabulary Use your sentences to help answer the questions.

Reviewing Key Concepts

1. a. Reviewing How are Earth and a bar magnet similar?
   b. Describing How do Earth's magnetic properties explain how a compass works?
   c. Interpreting Diagrams Look at Figure 12. How do the positions of the geographic and magnetic poles compare?
2. a. Identifying What are two effects of Earth's magnetic field?
   b. Explaining How can scientists use rocks to learn about Earth's magnetic field?
   c. Relating Cause and Effect What causes the part of Earth's magnetic field called the magnetosphere to exist?

Lab zone At-Home Activity

House Compass With a family member, explore your home with a compass. Use the compass to discover magnetic fields in your house. Try metal objects that have been in the same position over a long period of time. Explain to your family member why the compass needle moves away from north near some objects.

Chapter 19 Study Guide

The BIG Idea **Properties of Matter** Magnetic poles that are alike repel each other. Magnetic poles that are not alike attract each other.

1 What Is Magnetism?

Key Concepts

- Magnets attract iron and similar materials that contain iron. They attract or repel other magnets. In addition, one part of a magnet will always point north when allowed to swing freely.
- Magnetic poles that are unlike attract each other and magnetic poles that are alike repel each other.
- Magnetic field lines spread out from one pole, curve around the magnet, and return to the other pole.

Key Terms

magnet
magnetic pole
magnetic force
magnetic field
magnetic field lines

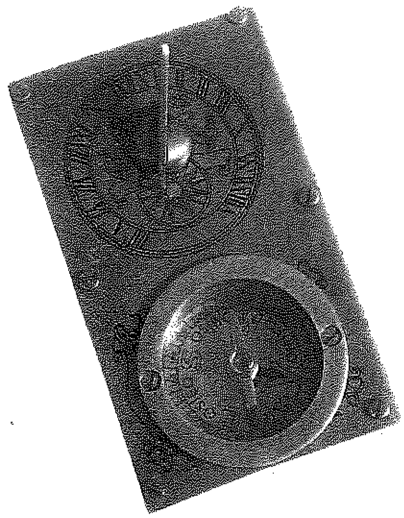
2 Inside a Magnet

Key Concepts

- A spinning electron produces a magnetic field that makes the electron behave like a tiny magnet in an atom.
- In a magnetized material, all or most of the magnetic domains are arranged in the same direction.
- Magnets can be made, destroyed, or broken apart.

Key Terms

- atom • element • nucleus • proton
- neutron • electron • magnetic domain
- ferromagnetic material
- temporary magnet
- permanent magnet



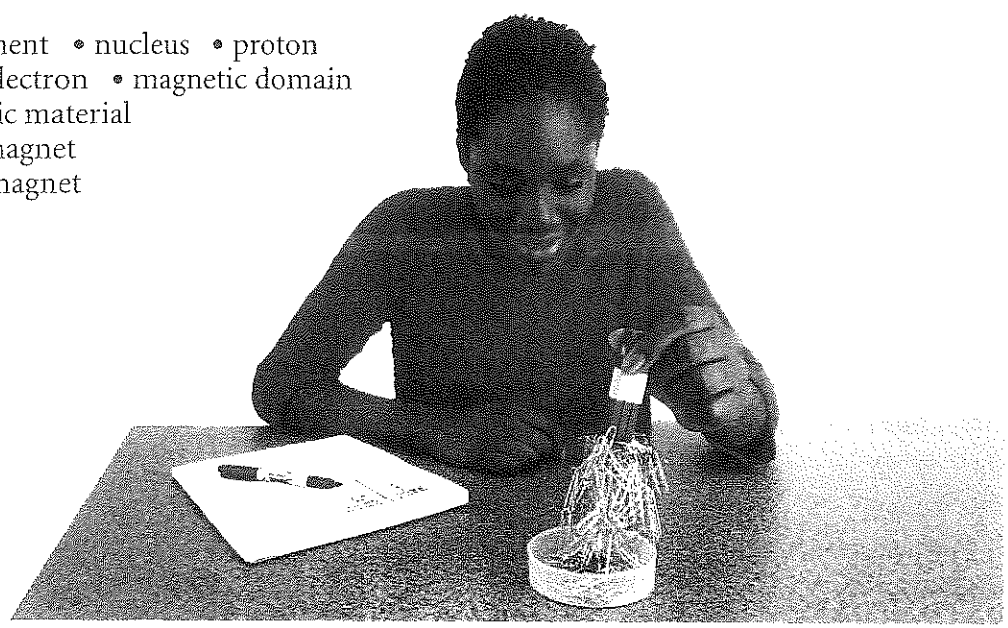
3 Magnetic Earth

Key Concepts

- Just like a bar magnet, Earth has a magnetic field surrounding it and two magnetic poles.
- Since Earth produces a strong magnetic field, Earth itself can make magnets out of ferromagnetic materials.
- Earth's magnetic field affects the movements of electrically charged particles in space.

Key Terms

- compass • magnetic declination • Van Allen belts
- solar wind • magnetosphere • aurora

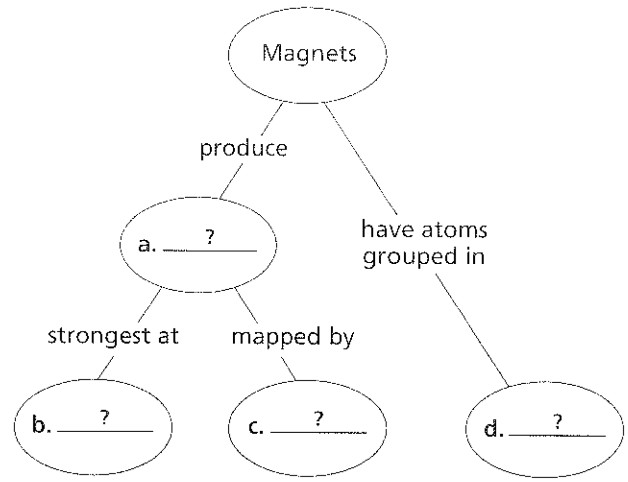


Review and Assessment

Go Online
PHSchool.com
For: Self-Assessment
Visit: PHSchool.com
Web Code: cga-4010

Organizing Information

Concept Mapping Copy the concept map about magnetism onto a separate sheet of paper. Then complete it and add a title. (For more on concept maps, see the Skills Handbook.)



Reviewing Key Terms

Choose the letter of the best answer.

1. The area of a magnet where the magnetic force is strongest is a
   a. magnetic pole.
   b. magnetic field.
   c. magnetic field line.
   d. magnetosphere.
2. The negatively charged particles within atoms are
   a. electrons.
   b. nuclei.
   c. protons.
   d. orbits.
3. An example of a ferromagnetic material is
   a. plastic.
   b. copper.
   c. wood.
   d. iron.
4. A compass works because its magnetic needle
   a. contains atoms.
   b. contains charged particles.
   c. repels magnets.
   d. spins freely.
5. A stream of electrically charged particles flowing from the sun is called the
   a. Van Allen belt.
   b. magnetosphere.
   c. solar wind.
   d. magnetic field.

If the statement is true, write *true*. If it is false, change the underlined word or words to make the statement true.

6. Magnetic field lines map out the magnetic field around a magnet.
7. In an atom, the electrons and protons are located in the nucleus.
8. A ferromagnetic material is a material like iron that has strong magnetic properties.
9. A magnet that keeps its magnetism for a long time is called a temporary magnet.
10. The region of Earth's magnetic field shaped by the solar wind is called the aurora.

Writing in Science

Research Report You are a geologist reporting about Earth's magnetic field. In your report, explain what causes the field and give information on how scientists study it.

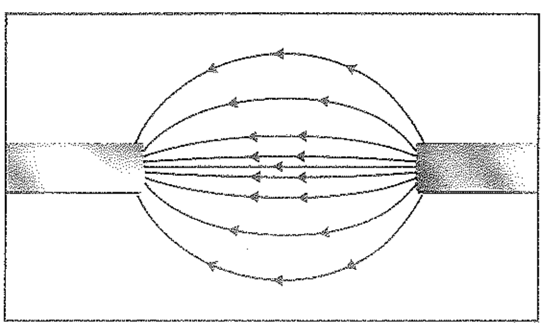
Review and Assessment

Checking Concepts

11. Explain how magnetic field lines are used to represent the field of a magnet. Draw a diagram that shows magnetic field lines around a magnet.
12. Describe the structure of an atom.
13. How do the atoms differ in materials that can be used as magnets and materials that cannot?
14. Describe the magnetic domains in a magnetized material.
15. Explain why you are not left with one north pole and one south pole if you break a magnet in half. Draw a diagram to support your answer.
16. How does a material become a magnet?
17. How does Earth act like a magnet?
18. What is an aurora? How is it produced?

Thinking Critically

19. Applying Concepts Examine the diagram below. Is the magnetic pole on the left a north or south pole? Are the two poles like or unlike?

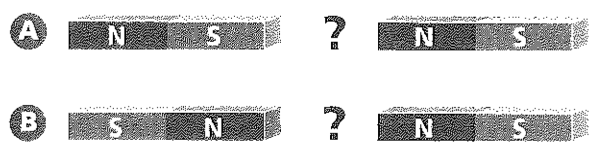


20. Applying Concepts The north pole of a bar magnet is held next to one end of an iron rod. Is the other end of the iron rod a north pole or a south pole? Why?
21. Inferring A compass points north until a bar magnet is brought next to it. The compass needle is then attracted or repelled by the magnet. What inference can you make about the strengths of the magnetic fields of Earth and the bar magnet?
22. Problem Solving Cassia borrowed her brother's magnet. When she returned it, it was barely magnetic. What might Cassia have done to the magnet?
23. Drawing Conclusions Why might an inexperienced explorer get lost using a compass?
24. Relating Cause and Effect What might happen to a metal pair of scissors if rubbed in one direction with the north pole of a magnet?

Applying Skills

Use the illustration to answer Questions 25–27.

The illustration shows two pairs of magnets.



25. Interpreting Diagrams Which pair of magnets will have a force of attraction between them? Which pair will have a force of repulsion between them? Explain your choices.
26. Predicting Suppose the left-side magnet in pair A traded places with the left-side magnet in pair B. Use magnetic field lines to make a sketch to show how the new pairs would look. Predict if the pairs will attract or repel. Explain.
27. Problem Solving If the poles of the magents were not identified, how could you identify them without using a compass?

Lab zone Chapter Project

Performance Assessment Present your sculpture to the class. Use a diagram of your sculpture to show the materials you used to create it and to show how the materials are connected to each other. Explain how you included any materials that were not originally magnetic.

Standardized Test Prep

Test-Taking Tip

Interpreting a Diagram

Some questions ask you to interpret a diagram. Examine the diagram in detail, paying attention to labels, titles, and arrows. Study the diagram of the magnetic field of an iron bar for Question 3 and answer the sample question.

Sample Question

The distance between the magnetic field lines on the diagram indicates that the magnetic field is

- **A** strongest where the lines are farthest apart.
- **B** strongest where the lines are closest together.
- **C** weakest where the lines are closest together.
- **D** uniform.

Answer

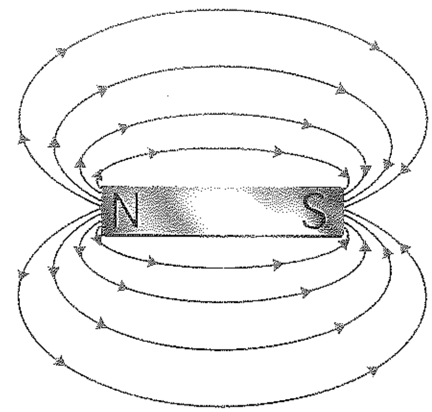
The correct answer is **B**. The distance between the magnetic field lines on a magnetic field diagram indicate the strength of the magnetic field, which is strongest where the lines are closest together.

Choose the letter of the best answer.

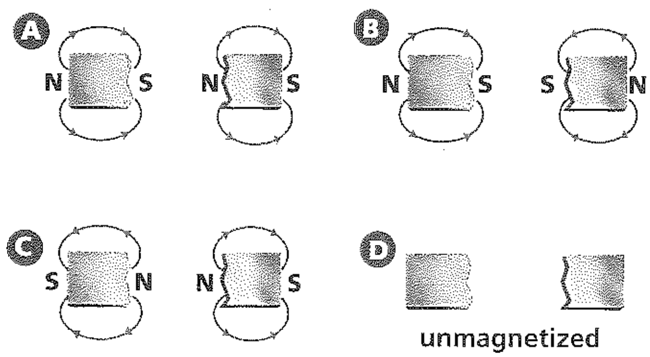
1. Maglev trains use magnets to elevate trains so that they never touch the tracks. The poles of the magnets on the trains facing the poles of the magnets on the tracks must be
   - **A** the same, so they attract each other.
   - **B** the same, so they repel each other.
   - **C** opposites, so they repel each other.
   - **D** opposites, so they attract each other.

2. In lab, Claudio rubs the north pole of a bar magnet against a wooden coffee stirrer, iron nail, and plastic spoon. After rubbing each item for 2 minutes, Claudio tries to pick up one steel paper clip using each object. The variable tested in this experiment was
   - **F** the magnetic strength of the bar magnet.
   - **G** time.
   - **H** the magnetic properties of selected materials.
   - **J** the amount of rubbing.

Use the diagram below to answer Question 3.



3. If the bar magnet in the above diagram were cut in half, which diagram below *best* represents the magnetic field of the two new pieces?



4. Which of the following statements *best* describes why compasses point north?
   - **F** Compasses, like all magnets, always point to the geographic North Pole.
   - **G** The magnetized compass needle aligns itself with Earth's magnetic field.
   - **H** Compass needles point toward the sun.
   - **J** The compass needle is repelled by Earth's geographic South Pole.

Constructed Response

5. A bar magnet picks up one paper clip. A second paper clip clings to the first paper clip but does not directly touch the magnet. Explain why the second paper clip clings to the first without touching the bar magnet.