Section 2 Inside a Magnet

Objectives

After this lesson, students will be able to

N.1.2.1 Explain how an atom can behave like a magnet.

N.1.2.2 Describe how magnetic domains are arranged in a magnetic material.

N.1.2.3 Explain how magnets can be changed.

Target Reading Skill

Asking Questions Explain that changing a head into a question helps students anticipate the ideas, facts, and events they are about to read.

Answers

Sample questions and answers: **What are the three particles that make up an atom?** *(Protons, neutrons, and electrons.)* **What are magnetic domains?** *(A grouping of atoms that have their magnetic fields aligned is called a magnetic domain.)* **How can magnets be made and changed?** *(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. A permanent magnet can lose some or all of its magnetism if it is hit hard or heated. If a magnet is broken in two, you have two smaller magnets.)*

All in One Teaching Resources

- Transparency N4

Preteach

Build Background Knowledge L2

Remind students that they have learned about atoms in past science classes. Ask: **What is an atom?** *(Sample answer: An atom is the smallest part of an element that has the properties of that element.)* **What are the particles that make up an atom?** *(Some students may know that protons, neutrons, and electrons make up atoms.)* Tell students that it is the electrons that give some materials magnetic properties. **Do any of those particles have a charge?** *(Some students may know that protons are positively charged and electrons are negatively charged.)*

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.

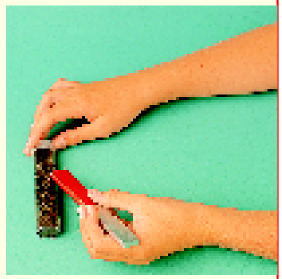
Inside an Atom

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. ▶

Lab zone Discover Activity

Skills Focus Drawing conclusions L1

Materials clear plastic tube, iron filings, strong bar magnet

Time 15 minutes

Tips Make sure students rub their plastic tubes in one direction. Suggest they start at the top of the tube, rub down to the bottom, and then begin again at the top.

Expected Outcome When a student rubs the tube, the iron filings become aligned and point in the same direction.

Think It Over Sample answer: The iron filings line up and point in the same direction because they have become magnetized by the rubbing of the bar magnet.

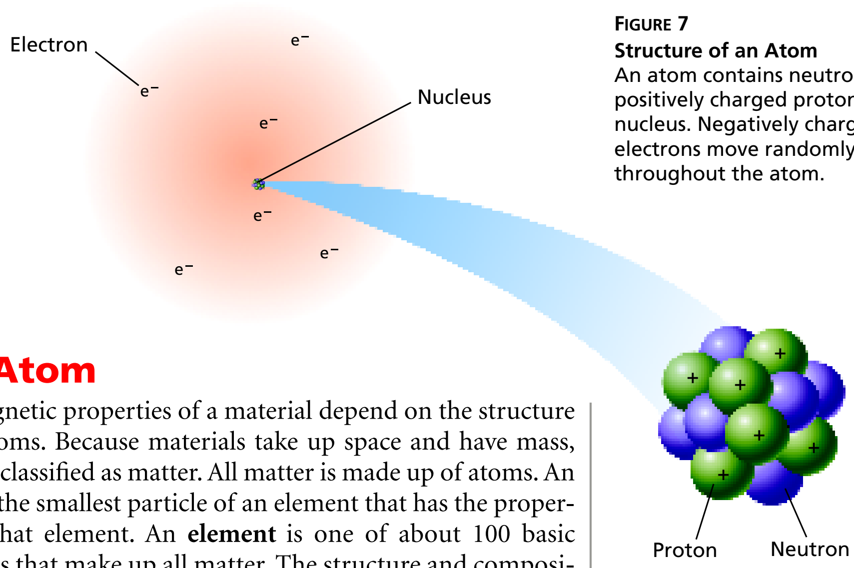


FIGURE 7
Structure of an Atom
An atom contains neutrons and positively charged protons in its nucleus. Negatively charged electrons move randomly throughout the atom.

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 that has the properties of that element. An **element** is one of about 100 basic materials 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?**

Instruct

The Atom

Teach Key Concepts L2

Electrons in Atoms

Focus Tell students that the magnetic properties of a material depend on the electrons of its atoms.

Teach Have a volunteer read the definition of an atom out loud. Ask: **What are the charges of the particles in an atom?** *(A proton has a positive charge, a neutron has no charge, and an electron has a negative charge.)* **What makes an electron behave like a tiny magnet in an atom?** *(The spinning of the electron produces a magnetic field.)* **What characteristic does an atom with strong magnetic properties have?** *(The atom has electrons that are not paired.)*

Apply Show students a strong magnet, and demonstrate its magnetic field by showing that it is attracted to iron. Ask: **What does this object's magnetic properties tell you about the electrons in its atoms?** *(This object has atoms that contain electrons that are not paired.)* **learning modality: verbal**

All in One **Teaching Resources**

- Transparency N5

Independent Practice L2

All in One **Teaching Resources**

- *Guided Reading and Study Worksheet: Inside a Magnet*

Student Edition on Audio CD

Differentiated Instruction

Special Needs L1
Interpreting Diagrams and Communicating Refer students to Figure 8, and tell them to use the figure as a guide in making their own drawings of magnetic domains in magnetized material and in unmagnetized material. Students should label their drawings and write a brief annotation explaining why each drawing is classified as it is. **learning modality: visual**

Gifted L3
Communicating Ask students to prepare a presentation to the class about why a refrigerator magnet sticks to a refrigerator door. Suggest these students create visual aids to help in their presentation. Through research, students will discover that the magnetic field of the refrigerator magnet aligns the magnetic domains of the door. **learning modality: verbal**

Monitor Progress L2

Drawing Have students make their own labeled drawing of an atom.

Students can keep their drawings in their portfolios. Portfolio

Answer

Reading Checkpoint In most atoms, electrons form pairs that spin in opposite directions. Opposite spins create opposite magnetic fields that cancel, leaving no net magnetic field.

Magnetic Domains

Teach Key Concepts

L2

Lining Up in the Same Direction

Focus Tell students that in magnetic materials, groups of atoms are lined up in the same direction.

Teach Ask: **What is a magnetic domain?** *(A grouping of atoms that have their magnetic fields lined up in the same direction)* Explain that individual atoms have magnetic fields, and billions of atoms together make up a magnetic domain. Ask: **How is a magnetic domain like a bar magnet?** *(A magnetic domain has a north pole and a south pole.)* **In a magnetic material, how are all or most of the magnetic domains arranged?** *(Most or all are arranged in the same direction.)*

Apply Use Figure 8 to differentiate between magnetized material and unmagnetized material. Ask: **How can you tell the top diagram in Figure 8 represents unmagnetized material?** *(The magnetic domains point in random directions.)* **How does this random arrangement prevent the material from being magnetic?** *(The magnetic fields of some domains cancel the magnetic fields of other domains.)* **learning modality: visual**

All in One Teaching Resources

- Transparency N6

Lab zone Build Inquiry

L2

Modeling Magnetic Domains

Materials 10-cm by 4-cm strips of construction paper, enough for each student to have 12 strips

Time 10 minutes

Focus Tell students they will model the magnetic domains in magnetized material and in unmagnetized material

Teach Give each student at least 12 strips of paper, and tell them to label the ends of each strip N and S to represent magnetic poles of individual magnetic domains. First have students arrange the strips in a way that shows an unmagnetized material. Then, have students arrange the strips in a way that shows a magnetized material.

Apply Ask: **When you model a magnetized material, how are the north poles of the magnetic domains aligned?** *(They all point in the same direction.)* **learning modality: kinesthetic**

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.

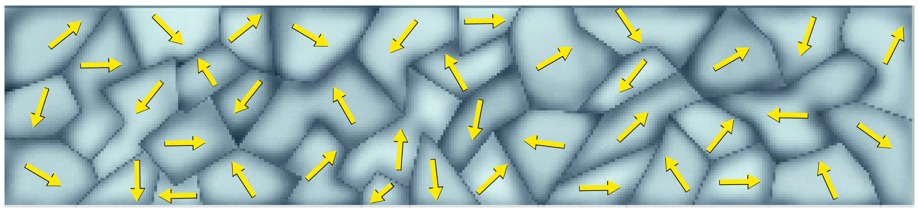
Alignment of Domains The direction in which the domains point determines if the material is magnetized or not magnetized. In a material that is not magnetized, the magnetic domains point in random directions, as shown in Figure 8. Therefore, the magnetic fields of some domains cancel the magnetic fields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

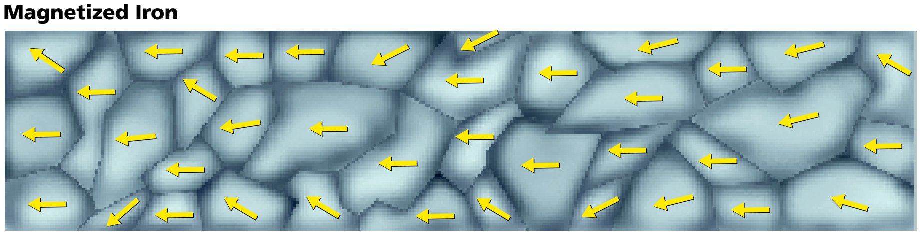
Reading Checkpoint **What is the arrangement of the magnetic domains in a material that is not magnetized?**

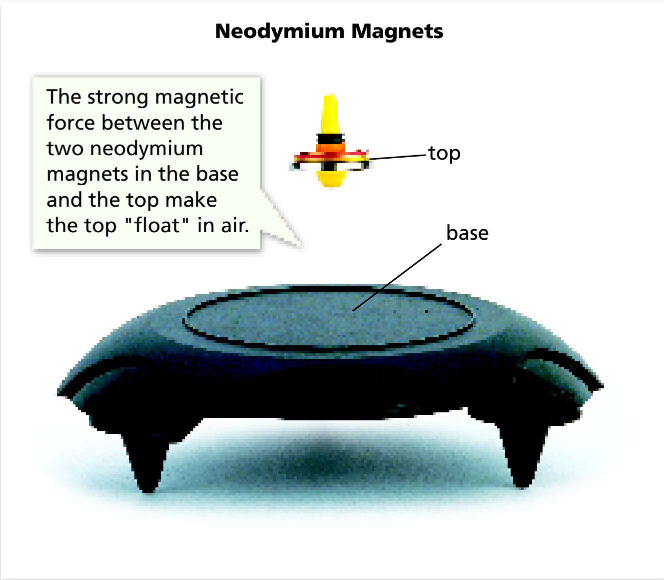
FIGURE 8
Magnetic Domains
The arrows represent the magnetic domains of a material. The arrows point toward the north pole of each magnetic domain.
Comparing and Contrasting *How does the arrangement of domains differ between magnetized iron and unmagnetized iron?*

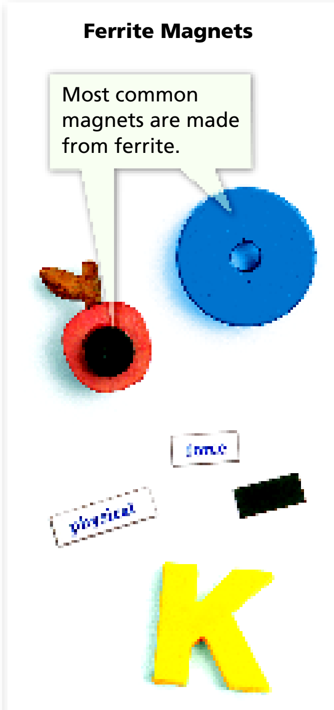
Unmagnetized Iron



Magnetized Iron







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?**

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

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

Help Students Read L1

Relating Text and Figures Refer to the Content Refresher in this chapter, which provides the guidelines for the Relating Text and Figures strategy.

Have students keep their books closed as you read aloud the paragraphs under the subheading *Alignment of Domains*. Then, have students open their books to the passage you read. Tell them to reread the passage and study Figure 8 carefully. Ask: **What parts of the text makes more sense now that you can see the figure?** *(Sample answer: Now I understand better the difference in the arrangement of domains in magnetized material and unmagnetized material.)* **What new information did you learn by looking at the figure?** *(Sample answer: The domains are all differently shaped, and the north poles of the domains point in all different directions in unmagnetized material.)*

Go Online SCiLINKS NSTA
For: Links on magnetic materials
Visit: www.SciLinks.org
Web Code: scn-1412
Download a worksheet that will guide students' review of Internet sources on magnetic materials.

Monitor Progress L2

Writing Have students write a paragraph explaining what causes a material to have magnetic properties. Ask them also to name one ferromagnetic material.

Answers

Figure 8 Most of the domains in magnetized iron are arranged in the same direction. Most of the domains in unmagnetized iron are arranged in random directions.

Reading Checkpoint The domains point in random directions.

Reading Checkpoint Iron, nickel, cobalt, gadolinium, neodymium, and samarium.

Differentiated Instruction

English Learners/Beginning L1

Comprehension: Modified Cloze
Distribute a simplified paragraph about the inside of a magnet, but leave some words blank. Model how to fill in the blanks, using a sample sentence on the board. Provide students with the correct answers as choices. **learning modality: verbal**

English Learners/Intermediate L2

Comprehension: Modified Cloze
Distribute the same paragraph in the Beginning strategy, but include some additional terms as incorrect answer choices. After students complete the paragraph, have them work together to write definitions for the answer choices not used. **learning modality: verbal**

Making and Changing Magnets

Teach Key Concepts L2

Making, Destroying, and Breaking Magnets

Focus Explain to students that magnets can be made and destroyed, and making and destroying magnets is common.

Teach Ask: **What are two ways a magnet can be made?** *(By placing an unmagnetized material in a strong magnetic field and by rubbing the material with one pole of the magnet)* **What is the difference between a temporary magnet and a permanent magnet?** *(A temporary magnet is made from a material that easily loses its magnetism, while a permanent magnet is made from material that keeps its magnetism for a long time.)* **What are two ways a magnet can be destroyed?** *(A magnet can be destroyed if it is dropped or heated.)*

Apply Demonstrate how to make a temporary magnet by rubbing a paper clip with one pole of a bar magnet. Then show students how that paper clip will attract another paper clip. Ask: **What did the magnetic field of the bar magnet cause to occur in the paper clip?** *(It caused some magnetic domains in the paper clip to line up in the same direction.)* **learning modality: visual**

Use Visuals: Figure 11 L1

A Magnet Cut in Half

Focus Tell students that breaking a magnet in half does not destroy the magnet.

Teach Have students look at Figure 11 and read the caption. Ask: **What happens if you break a magnet in two?** *(The result is two smaller magnets.)* **Why does breaking a magnet in half result in two smaller magnets?** *(In a magnet, many domains are lined up in one direction, producing strong magnetic forces at the poles. If the magnet is broken in half, the domains will still be lined up in the same way in the smaller pieces.)*

Apply Explain that this breaking process can continue until the magnets are extremely small. Ask: **What is the smallest thing that has the properties of a large magnet?** *(An atom)* **learning modality: verbal**

All in One Teaching Resources

- Transparency N7

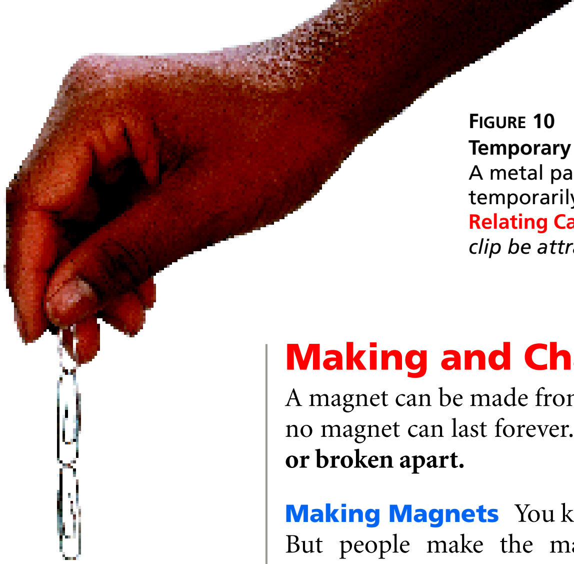


FIGURE 10
Temporary Magnets
A metal paper clip can be magnetized and temporarily attract another paper clip.
Relating Cause and Effect *How can a paper clip be attracted to another paper clip?*

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**.

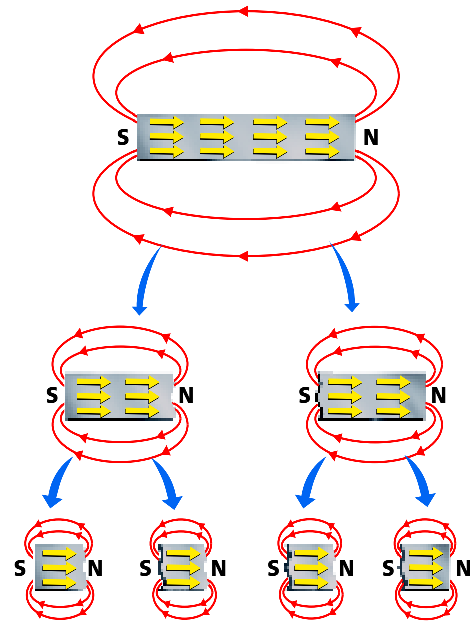
Destroying Magnets Like a temporary magnet, a permanent magnet can also become unmagnetized. One way for a magnet to become unmagnetized is to drop it or strike it hard. If a magnet is hit hard, its domains can be knocked out of alignment. Heating a magnet will also destroy its magnetism. When an object 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 Chapter Project

Keep Students on Track Check that each group has completed or is well on its way to completing a design for a magnetic sculpture. Ask students what materials they plan to use, and provide materials or suggest places to obtain needed materials. Ask questions such as the following: What kinds of magnets are you using in your sculpture? How many magnets are you using?

Writing in Science

Writing Mode Writing dialogue

Scoring Rubric

4 Exceeds criteria
3 Meets criteria
2 Meets some criteria; fails to explain completely and/or accurately what occurs when a magnet is broken
1 Includes serious errors or is incomplete

Monitor Progress L2

Answers

Figure 10 Placing a paper clip in a magnetic field causes its domains to be arranged in the same direction, making it a temporary magnet that attracts other clips.

Reading Checkpoint A magnet made from a material that easily loses its magnetism

Assess

Reviewing Key Concepts

1. a. Protons, neutrons, and electrons **b.** Electron **c.** A spinning electron produces a magnetic field that makes the electron behave like a tiny magnet in the atom.
2. a. A grouping of atoms with their magnetic fields lined up in the same direction **b.** In magnetized materials, all or most domains are arranged in the same direction. In unmagnetized materials, most domains point in random directions. **c.** The magnet's magnetic field causes most domains in the filings to line up with the magnetic field of the bar magnet.
3. a. A magnet can lose some or all of its magnetism if it is hit hard or heated above a certain temperature. It can also be broken into smaller magnets. **b.** Both are made of ferromagnetic materials. Temporary magnets are made of materials that are magnetized easily but lose their magnetism quickly. Permanent magnets are made of materials that are harder to magnetize but tend to keep their magnetism longer.

Reteach L1

Call on students to explain domains and how they are arranged in magnetized and unmagnetized materials.

Performance Assessment L2

Skills Check Have each student make a flowchart that explains how a temporary magnet can be made. Make sure students mention magnetic domains.

All in One Teaching Resources

- *Section Summary: Inside a Magnet*
- *Review and Reinforcement: Inside a Magnet*
- *Enrich: Inside a Magnet*

Lab zone Technology Lab

Design and Build a Magnetic Paper Clip Holder

L3

Prepare for Inquiry

Key Concept

Combining the magnetic fields of magnets produces a stronger magnet.

Skills Objectives

After this lab, students will be able to:

- design a magnetic paper clip holder
- evaluate the design and performance of the magnetic paper clip holder
- troubleshoot the magnetic paper clip holder for problems and redesign it

Prep Time 10 minutes

Class Time 40 minutes

Advance Planning

Collect two bar magnets for each student or group and an assortment of other magnets of various types, shapes, and sizes. In addition, you'll need a box of paper clips and a roll of masking tape for each student or group. To make the base and strapping for the holder, each student or group will need modeling clay and string. Rubber bands might be useful in building a holder. Students might also request a foam or wooden base.

All in One Teaching Resources

- Lab Worksheet: *Design and Build a Magnetic Paper Clip Holder*

Guide Inquiry

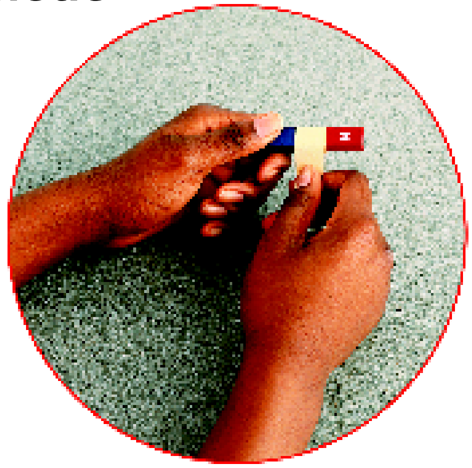
Introduce the Procedure

Using two bar magnets, review with students the two polar ends of magnets. Review how unlike poles attract and like poles repel. Then, have students read the entire procedure, and answer any questions they have. Ask: **Why do you think you need to do three trials for each magnet and then find the average for the three?** *(To make sure you get a true reflection of the strength of the magnet and not a fluke on just one trial)* **What materials do you think you might need to make the holder?** *(Sample answer: A base might be useful, such as one made of foam or wood.)*

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

- 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 paper20 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.

Sample Data Table

Type of Magnet	Number of Paper clips
Bar Magnet—north pole	12
Bar Magnet—north pole	13
Bar Magnet—north pole	11
Ceramic Magnet—south pole	9
Ceramic Magnet—south pole	8
Ceramic Magnet—south pole	8

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

Expected Outcome

Students should discover that combinations of magnets are more powerful than any single magnet.

Analyze and Conclude

1. Sample answer: Testing three times ensures that a mistake or an odd result does not skew the data.

2. Sample answer: Different magnets have different strengths. Generally, combining magnets results in a stronger magnetic field.

3. The combination of magnets that picked up the most paper clips has the strongest magnetic field and was used in the holder design.

4. Sample answer: One problem was exposing enough of the surface of the magnets while securing them in place on a modeling clay base. To solve this problem, the clay base was reshaped.

5. Sample answer: The design constraint of holding that many paper clips meant that the design had to include a way of holding several magnets in place. That problem was solved using tape and string.

6. Sample answer: Magnets are used on a purse clasp to keep its contents from falling out.

Extend Inquiry

Communicate Students' letters will vary. An excellent letter will clearly and logically explain how to combine magnets to produce a more powerful magnet, including how to align the poles of a bar magnet. Students should also explain why combining magnets produces a more powerful magnetic field.

Troubleshooting the Experiment

- Combining magnets for greater strength will work with traditional bar magnets and will also work with ceramic magnets.
- If students work with disk magnets, advise them that they may get better results by combining magnets by unlike poles. Combining bar magnets, by contrast, works best when like poles are combined—one magnet on top of the other, both oriented the same way.
- As you check the students' drawings made in Part 2, suggest ways in which students can improve their designs. Help students find simple materials they request for use in their holders.

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Students can share data online.