3-D Magnetic Field Jar

Physical Science Demonstration Kit

Introduction

A magnet exerts an invisible force on certain objects. The force emanating from a magnet, the *magnetic field,* is often depicted by lines extending from one pole of the magnet to another. These "lines of force" can be beautifully demonstrated in three dimensions by using a jar filled with a viscous medium and iron filings.

Concepts

- Ferromagnetic material
- Magnetic field
- Magnetic domains
- Magnetic poles

Materials

Iron filings, Fe, non-rusting alloy, 10 g*

Mineral oil, 500 mL*

Water, tap

Compass, miniature (optional)

Cow magnet*

Jar with drilled lid and tube*

Magnets, various sizes and shapes (optional)

Paper towels

Tape (optional)

Tweezers or magnetic stir bar retriever

**Materials included in kit.*

Safety Precautions

Keep the magnets away from electrical equipment. Wear chemical splash goggles and chemical-resistant gloves while setting up the model initially. Encourage students to follow all normal laboratory procedures when handling the model. Please review current Material Safety Data Sheets for additional safety, handling, and disposal information.

Preparation

1. Fill the glass jar with tap water.
2. Screw the cap onto the jar allowing excess water to leak out. Remove the cap and use a piece of tape to mark the glass jar at the level of water remaining in the jar. *Note:* This should come to about ~450 mL.
3. Pour out the water and dry the inside of the jar with a towel.
4. Add the entire bottle of 10 g of iron filings to the empty glass jar.
5. Fill the jar with mineral oil up to the line of tape.
6. Slowly screw on the cap of the jar allowing any excess mineral oil to leak out. Tighten the cap carefully but firmly. *Optional:* To further seal the jar, circle the jar lid with tape several times.
7. Invert the jar several times to check for a good seal. If mineral oil leaks out, either tighten the cap or further secure it using tape.

Procedure

1. Tightly grip the jar by both the base and lid and shake and rotate to distribute the iron filings evenly throughout the mineral oil.

2. Slide the cow magnet into the tube within the jar and continue to rotate the jar in your hands.
3. Place the jar on the counter and allow the filings and bubbles to settle. *Note:* Ideally, the filings should be evenly distributed around the magnet, the poles and the field lines. Display the filing orientation to the students.
4. Remove the magnet with a pair of tweezers or magnetic stir bar retriever.
5. Test with various other types of magnets to demonstrate their magnetic fields.
6. *(Optional)* Use a miniature compass to determine the polarity of the magnet—the red needle will point toward the magnet's north pole.

Disposal

Please consult your current *Flinn Scientific Catalog/Reference Manual* for general guidelines and specific procedures, and review all federal, state and local regulations that may apply, before proceeding. The 3-D Magnetic Field Jar may be stored and reused.

Tips

- This kit contains enough materials to create one 3-D Magnetic Field Jar, which may be re-used indefinitely.
- Cow magnets are used by farmers to pick up iron such as bailing wire, etc., that a cow may ingest. If eaten, this iron can actually pierce the cow's stomach and do damage to vital organs. In fact, the problem of ingested iron has a name, Hardware Disease. The magnet keeps the iron in the center of the stomach so piercing does not occur. The magnet is an alloy such that it is below hydrogen in the series while iron is above. As a result, the iron would oxidize before the magnet.
- Test the jar with various other magnet shapes and types—horseshoe, face-pole, ring, etc. For magnets that do not fit in the tube, such as a horseshoe magnet, attach the magnet to the outside of the 3-D magnetic field jar after shaking.
- Also test various arrangements, such as having the same pole of two magnets facing each other in the tube.
- If the jar is leaking, consider sealing with paraffin wax or tape. Mineral oil may be replenished by ordering from Flinn (500-mL, Catalog No. M0064) or purchasing at a local store.

Discussion

Since ancient times, it has been observed that a mineral known as lodestone exhibited a strange attractive force toward other materials containing this mineral. This attractive property was called *magnetism*. Although many scientists studied magnetism over the centuries, the origin and cause of this force was still a mystery until more recent history. After the discovery of the electron in 1897 by J. J. Thomson (1856–1940), it was verified that the interaction of the electrons in the atoms determines whether a material can be magnetic.

Every electron spinning around the nucleus of an atom acts like a tiny magnet. In most materials, the forces of these tiny magnets are balanced so there is no net magnetic effect. In *ferromagnetic* materials such as iron, nickel, and cobalt, the atoms possess electrons that are not balanced by other electrons. Normally, groups of these unbalanced electrons, known as *magnetic domains,* point in random directions. In this case the magnetic forces of the domains cancel each other out and the material is not magnetized (see Figure 1*a*). However, in the presence of a magnetic force such as the magnetic field around a permanent magnet, the magnetic domains of a ferromagnetic material begin to align with the magnet's lines of force. The material becomes a temporary magnet (see Figure 1*b*). When the external magnetic field is removed, the magnetic domains will again point in random directions and the material will lose its magnetic property. In order to form a permanent magnet, a ferromagnetic material must be formed or processed in such a way so that the magnetic domains are aligned and "locked" in one direction and do not become randomly oriented over time (see Figure 1*c*).

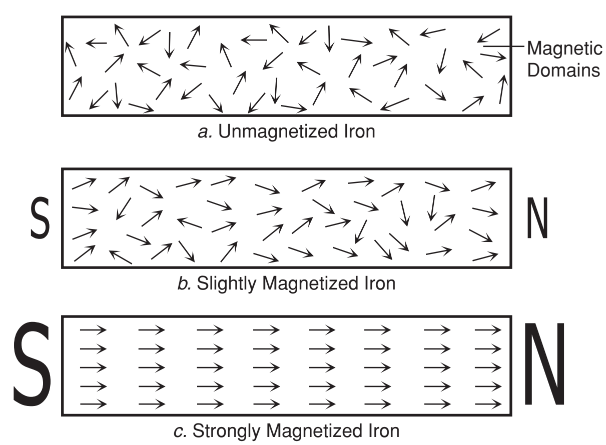

Figure 1.

The strength of a magnetic field is not constant, but varies with distance from the *magnetic poles* of the magnet. Each magnet has two poles, a north pole and a south pole, so named because if allowed to move freely, the north pole of a magnet will point toward the Earth's North Pole. The magnetic lines of force travel from the north pole of a magnet to the south pole. The magnetic field does not stop at the poles, however, it continues through the magnet, forming a continuous loop (see Figure 2). If a magnet is broken into two pieces, a continuous loop forms around each piece, so each piece becomes a separate magnet with north and south poles.

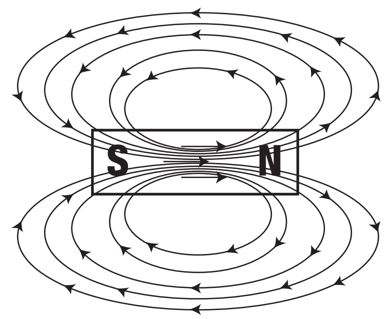

Figure 2.

In this demonstration, ferromagnetic iron fillings are held in mineral oil, providing the viscosity to slow and evenly distribute the filings and artistically demonstrate the magnetic field. When the jar is shaken and a cow magnet is inserted in the plastic tube, the iron filings will line up along the magnetic field created by the magnet, creating a 3-D representation of the magnetic field.

Connecting to the National Standards

This laboratory activity relates to the following National Science Education Standards (1996):

Unifying Concepts and Processes: Grades K–12
Systems, order, and organization
Evidence, models, and explanation
Content Standards: Grades 5–8
Content Standard B: Physical Science, properties and changes of properties in matter, understanding of motions and forces, transfer of energy
Content Standards: Grades 9–12
Content Standard B: Physical Science, structure of atoms, structure and properties of matter, motions and forces, interactions of energy and matter

Answers to Worksheet

Observations

Sketch the magnetic field of the cow magnet, as well as any other magnets used in the demonstration.

Discussion Questions *(Student answers will vary.)*

1. How might the north pole of an unmarked magnet be determined?

   The north pole cannot be determined from the arrangement of the iron fillings alone. Instead, a compass or a magnet with known poles must be used to find out which side of the magnet is the north pole. The magnet may be suspended by a string and allowed to rotate freely. The end pointing north would be the North Pole.

2. Describe the arrangement of the iron filings if the cow magnet were broken in half, and one of the halves was placed in the tube.

   The iron fillings would show the same structure, but half the size. Breaking the magnet in half will just create two smaller magnets, both with a north and south pole.

3. What can be concluded about the strength of the magnetic field in relation to the distance from the magnet? What evidence supports this conclusion?

   The iron filings are more densely concentrated around the poles. Additionally, the lines of force become less distinct as the distance from the magnet increases because the filings are more random in orientation. This indicates the magnetic force becomes weaker as the distance from the magnet increases.

Materials for *3-D Magnetic Field Jar—Physical Science Demonstration Kit* are available from Flinn Scientific, Inc.

Catalog No.	Description
AP7347	3-D Magnetic Field Jar—Physical Science Demonstration Kit
AP5666	Neodymiun Magnet
AP9266	Horseshoe Magnet

Consult your *Flinn Scientific Catalog/Reference Manual* for current prices.

Name: ____________________________________

3-D Magnetic Field Jar Worksheet

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