Magnetic Personalities: The Properties of Magnets

Introduction

Just about every student in the world has probably seen or played with magnets. But magnets are more than mere toys and are fascinating to explore. In technology and science, the study of magnets and how they produce and conduct energy has led to many advances in motors, generators and speakers. They have also made possible a life-saving medical technology called Magnetic Resonance Imaging. Most recently, engineers and scientists have used magnets to explore the potential of superconductivity, a topic increasingly in the news.

In this activity, students will explore magnetic personalities-or the properties of magnets-and will be able to relate those properties to real world engineering and science.

Grade Level

6th-8th grade.

The activity can be adapted to 4th and 5th grades too if some of the more technical material is omitted.

Objective

Upon completion of this lesson the student will be able to:

1. Understand some of the properties of magnets and magnetic materials.
2. Relate magnetism and electricity.
3. Discuss uses of magnets in the real world.
4. Discuss magnetic uses in the future.
5. Relate the properties of magnets to the construction of the electromagnets at the Superconducting Super Collider (SSC). (See instructor notes.)

Materials

- A set of magnets for the class. Magnets are available from many different sources. Inexpensive ceramic magnets can be found at electric motor shops as scrap. Another source is the toy store. If you live in a rural area, you may want to check into getting some "cow magnets:' (See the magnetic uses sheet.) Old stereo speakers can also be a good source of magnets.
- A jar of iron filings
- Glass jar filled with glycerin and iron filings
- Compass
- Approximately two feet of 18-gauge enameled wire
- Two D-cell batteries Overhead projector
- A loadstone sample

Procedure

The basic lesson takes 15 to 20 minutes; ideas for extended activies are also included.

1. The most interesting way to introduce the concept of magnetism is simply to have the students play with magnets and list on the chalkboard any observations. Pass out two magnets to groups of students and have them list their observations. You may need to prompt the students to get them started.

Here are some examples of what the students may observe

A. Have two poles: one north and one south
B. Like poles press apart same poles pull together
C. Magnets are usually made of metal
D. Magnets vary in strength

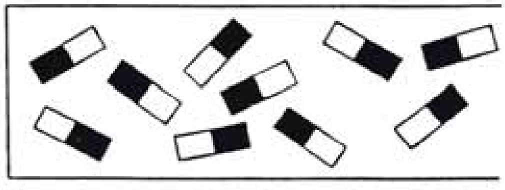
2. Show the students a lodestone. Lodestone is a natural magnet that is primarily used as a rich iron ore. Explain to the students that the observations they have made are true for all magnets. For example, no one has ever found a magnet with. only one pole

3. After introducing the properties of magnetism and discussing what the students have written on the board, check their understanding of the concept of poles. It is important that in this lesson the students learn that <u>like poles repel</u> and <u>unlike poles attract</u>.

4. Demonstrate again the state of the lodestone: "We know that this mineral is magnetic because of the large amount of iron present. We also know that the earth is magnetic because it too has a tremendous amount of iron in its core. But not everything that is iron is magnetic! Have you eve seen an iron nail that didn’t act like 2 magnet? What is special about magnets?"

Notes for the instructor

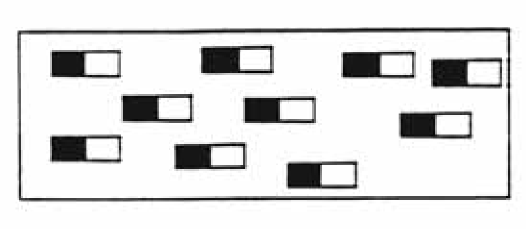
Unmagnetized molecules are not arranged in any particular order.



Magnetized molecules are arranged in an orderly manner.

Scientists use the Domain Theory to help explain magnetism and its inconsistent behavior in different samples of the same material The Domain Theory helps answer the questions: "Why are some magnets stronger than others?" and "'Why are some samples of iron magnetic while others are not? "

A domain is an individual molecule of a substance that exhibits a magnetic field. Each domain in a substance is really a separate magnet. Most of the time; domains are arranged in a random configuration. However, when they up in an orderly fashion all of the domains act as one, giving the magnet sufficient strength to behave as a magnet.



It is known that many rocks formed in the earth contain a lot of iron. Lodestone, the first magnet, which was discovered by the Greeks, is actually a rock loaded with the mineral magnetite. Magnetite is a rich iron ore. When it forms deep within the earth, it exists in a liquid state. It is at this time that the iron domains in the magnetite adjust themselves to the polarity of the earth and line themselves up with the north magnetic field. If enough of the magnetite domains adjust themselves, the magnetite will be magnetic. The more domains adjusted, the stronger the magnet.

Demonstration 1

a. After discussing the concept of domains with the students, borrow one of the magnets they were using to define the properties of a magnet. Tell them that you are now going to demonstrate to them the **magnetic field** which is simply the area of space affected by the force of the magnet. It is strongest at the poles and radiates from north to south.

b. Sprinkle iron filings over a clear transparency laid on top of a magnet while showing it on the overhead projector. Tap the transparency lightly until the magnetic field is displayed by the orderly iron filings.

c. Explain to the students that although they cannot “see" a magnetic field, they can feel it and see its effects. Tell them that what they are looking at is the effect of the magnetic field on the iron filings.

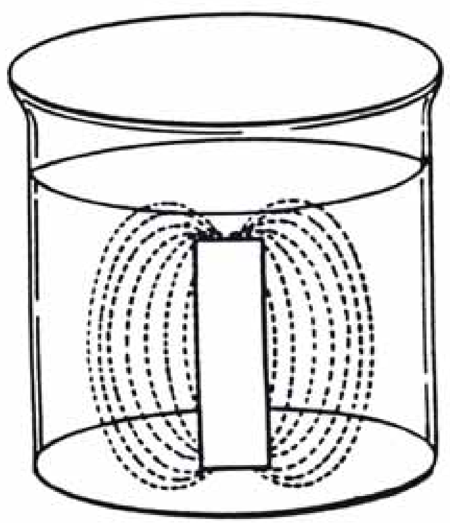
Demonstration 2

Now explain to the students that the magnetic field radiates from the magnet in all directions. It is three dimensional. Tell them that you are now going to demonstrate for them a three dimensional magnetic field.

a. Fill a clear glass jar with a clear viscous liquid. (Glycerin is best and is available at most drug stoves. You can also use vegetable oil, but it doesn’t work as well.).

b. Mix into the liquid the iron filings you were using in Demonstration 1. Stir the mixture while you ask the students “What do you suppose will happen if I put a magnet in this liquid?” Discuss their responses.

c. Place a very strong magnet in the liquid. The stronger the magnet, the better because the iron filings are being held in place by the liquid.



Demonstration 3

“In the 1800’s people were fascinated by magnets and by another strange phenomenon called electricity. Some scientists argued that the two forces were related while others argued that they were not. An experiment was conducted to find out who was right.”

Continue the experiment as you carry on this discussion.

“A compass was placed next to a wire hooked up to two D-cell batteries. Notice what happens to the compass needle when the power is switched on.” (The compass needle will wiggle a bit. Be sure not to leave the current on too long because the wire will begin to get hot.) Try the experiment several times moving the compass around the overhead projector.

"What makes the compass wiggle? Before you answer this question, ask yourself what a compass really is”. (The students will eventually come to see that a compass is a small magnet mounted in a way that leaves it free to spin.)

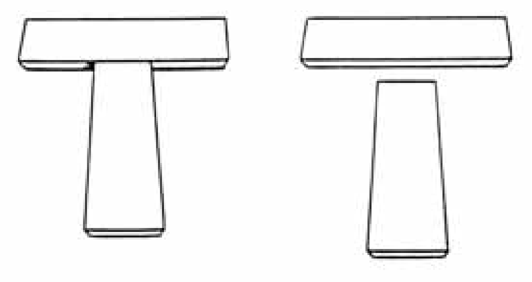
“And how, do we move magnets around without actually touching them? I saw same of you sliding them around your desk without touching them. How did you do that"? (The students will explain that opposite poles attract and like poles repel.) "So what was produced in this wire to make the compass wiggle?" (A magnetic field is the answer.)

Write on the board:

A Current Produces a Magnetic Field.

Extended Activities

1. A brain teaser
   Show the students a magnet and an ordinary iron bar. Have them attempt to tell you which is which. Have them use only the two objects and nothing else. Materials needed: iron bar magnet (Make sure the bar and the magnet look exactly alike. Painting helps to increase the resemblance (Suggestion: Work from the center outward. A magnet is always stronger at its poles.



2. Discuss some of the uses of magnets in, the students' lives and ask them what lies in the future.

Topics for Discussion

A. Magnets are used in motors and in generators to produce and use electrical energy. Magnets are used in speakers to produce sounds.
B. Cow magnets are cylinder-shaped magnets that are forced down a cow’s throat to lie in the first of the cow's four stomachs. There the magnet will attract staples, nails or wire that the cow accidentally eats and protects it from serious injury.
C. Magnetic Resonance imaging
The human body is made up of atoms that, like all other atoms, spin and vibrate this activity causes the atoms to create their own electric and magnetic fields. The process of Magnetic Resonance Imaging (MRI) uses these properties of atoms to create pictures of the internal structures of the body without actually going inside. Here’s how MRI works:
Living things are made up of about 90 percent hydrogen and most of that hydrogen is found in water molecules. When the body is placed inside a huge MRI magnet with a magnetic field a thousand times stronger than the earth's, the magnet causes all the atoms of hydrogen in the body to line up along its magnetic field lines. Then, radio waves that will knock the hydrogen atoms out of alignment are released into the body. When the radio waves are turned off again, the hydrogen atoms will jump back into alignment with the magnetic field of the MRI This time, as they jump they emit altered radio waves that a special coil (antenna) picks up, detects, and amplifies many times. The amplified waves are translated into an

image that can be seen by a doctor with the help of a computer.

How the image turns out depends on the strength of the altered radio waves. That in turn depends on the number of hydrogen atoms present and how "tightly" they are he together with other atoms. Where there are 0nly a few hydrogen atoms present, as in bone, the picture will appear lighter in that area. Where there are many, as in water, the picture will appear darker If the hydrogen is combined with many other atoms in a complex molecule like a protein, the hydrogen atoms are more tightly bound and are slower to bounce back in line with the magnetic field. This is helpful to doctors trying to determine whether a tumor is filled with fluid and is, therefore, non-cancerous (benign), or solid and, therefore, most likely to be cancerous (malignant).

The most desirable feature of MRI scanning is that the body is not exposed to radiation. Although radio waves are a part of the electromagnetic spectrum, they are very low energy waves that do not harm the body in any way. The effects of strong magnetic fields on the body are minimal, if they are measurable at all.

D. How Does the Superconducting Super Collider (SSC) Fit In?

The ability to make magnets that will produce magnetic fields 1,000 times stronger than the earth's is credited to high-energy physics research such as that being done at the SSC. Scientists who perform research at particle accelerators developed superconducting magnets by using special, low resistance metals combined with super-cold temperatures. They needed exceptionally strong magnets to guide protons around the accelerator ring at nearly the speed of light.

3. What's in store for the future? Discuss these ideas for the classroom.

Notes About Superconductivity and Superconductors

Most metals conduct electric current more readily as they are cooled but a few special metals and alloys lose all trace of electrical resistance at very low temperatures. In these superconductors as we call them currents flow uninhibited and will persist forever once started.

The enormous potential of this discovery, made by the Dutch physicist Kamerlingh Onnes in 1911 is now easy to see. In electrical devices, the barrier to higher efficiency is, power loss; the energy needed to push the current along is spent as heat. When superconducting wires are used, the problem vanishes. Unfortunately, immersion in liquid helium was the only way to achieve the extremely low temperature needed for super conductivity to occur, and for this reason it remained merely a laboratory curiosity until very recently.

The possible rewards of this technology far high-energy physics were so great that an enormous effort was made to realize superconductivity on a large scale. The effort paid off brilliantly in 1983, when protons first passed through the liquid-helium-cooled magnet of the Fermilab accelerator at Batavia, Illinois. Large superconducting magnets were already being used at Fermilab in the 15-foot bubble chamber before 1983.

The superconducting magnets at the Superconducting Super Collider (SSC) are not only more efficient than conventional ones, but they have higher currents and can generate stronger magnetic fields. This allows accelerators to achieve much higher energies using rings that are not impractically large. For the SSC, superconductivity is more than a clever technological trick: it is what makes the entire machine possible.

It was the successful operation of the Fermilab accelerator that demonstrated the feasibility of building a superconducting accelerator on the scale of the SSC. Liquid helium and liquid nitrogen will blanket the superconducting coils and the iron cores of the magnets. Careful design ensures that the SSC rings, including the refrigeration system, will consume only about a hundredth of the power needed for 2 similar rings of conventional magnets.

Even superconductors like the niobium-titanium alloy to be used in the SSC cannot carry an unlimited amount of current. At some point, trying to push more current through causes the material to revert to its normal, nonsuperconducting state. Superconductivity has moved from the laboratory to the factory via a collaboration between industry, universities, and U. S. national laboratories. New commercial applications are already coming to light, e.g. low-cost electric transmission lines (half the energy transmitted through lines in the United States is lost as heat!); long-term energy storage systems; magnetic imaging devices for medical diagnostics (see above); high-speed magnetically levitated trains and magnetically levitated boats. Such ideas have been brought closer to reality because of the need in high-energy physics for large-scale, high-quality systems of superconducting magnets.

Sponsor

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