Activity 1: Measuring Magnetism

"Science is built up with facts, as a house is with stones. But a collection of facts is no more a science than a heap of stones is a house." - Jules Henri Poincare

Activity Summary

Students will learn about the magnetic fields of a bar magnet. By the end of this activity, the students should know specifically that bar magnets have two "poles" and that similar poles repel and different poles attract. They should also know that although magnetic fields are invisible they can be measured and they have a direction.

National Science Content Standards

- Unifying Concepts and Processes: Evidence, models, and explanation ; Change, constancy, and measurement
- Science as Inquiry: Abilities necessary to do scientific inquiry ; Understandings about scientific inquiry
- Physical Science: Properties and changes of properties in matter ; Motions and Forces
- History and Nature of Science: Science as a human endeavor ; Nature of Science ; History of Science

Materials Needed per group of students

- 2 Magnetic Compasses per student
- 2 Strong Bar Magnets
- 4-5 Paper Clips, and a wooden or plastic ruler
- Iron Filings and 4 very thin sheets of paper (optional)

Additional Materials (for demonstration)

- Cow Magnet
- Small/medium sized bottle (clear plastic or glass)
- Manila Envelope
- Scotch tape (duct tape would be fine too)

Activity Outline

1. The lesson should begin with an introductory discussion with the students about magnetism. Ask your students about their experiences with magnetism and their knowledge and ideas about what it is and what causes it. Ask questions about whether or not Earth is magnetic, how they know if it is or not, and if there are any other astronomical bodies that are magnetic (like the Sun). You might also ask if they know what a magnetic compass is and what it does. If you wish, you can read the story of the STEREO-IMPACT NASA mission found in the "Background" section as a "hook" into the magnetism lesson.

   One key point of this discussion is trying to flush out any misconceptions that may be in students' minds about magnetism. One such misconception is that magnetism needs to be transmitted through a medium.

2. With two strong bar magnets (with N and S labeled for the magnetic poles) students should be allowed some time to freely experiment with the magnets and record their observations (see worksheet 1.1). You may make some suggestions about trying to get the magnets to attract or repel each other and attract or repel other objects such as paper clips, wooden rulers, or plastic pens. Have the students take notes on their discoveries (again see worksheet 1.1). The goals here are for them to discover that magnets attract metals but not other materials. Also you may want to steer them toward discovering the fact that when a metal is touching a magnet it becomes magnetic itself: i.e. if you touch one end of a paperclip to a magnet, the other end will attract other paper clips.

3. Now the class should be given magnetic compasses. First, discuss with the students what they know about compasses. How do they work? Bring out the fact eventually (after ample discussion) that the compass needle is a tiny magnet suspended on a pivot (so that it will turn with minimal friction if a magnetic force is applied to it). Then let the students experiment with bringing the compass near their bar magnets, first with one bar magnet and then with pairs of bar magnets in random configurations. Have them take notes and make sketches about what they discover (see worksheet 1.1). Make sure at some point to have the students arrange their compasses around one of the bar magnets as shown in Figure 1.1.

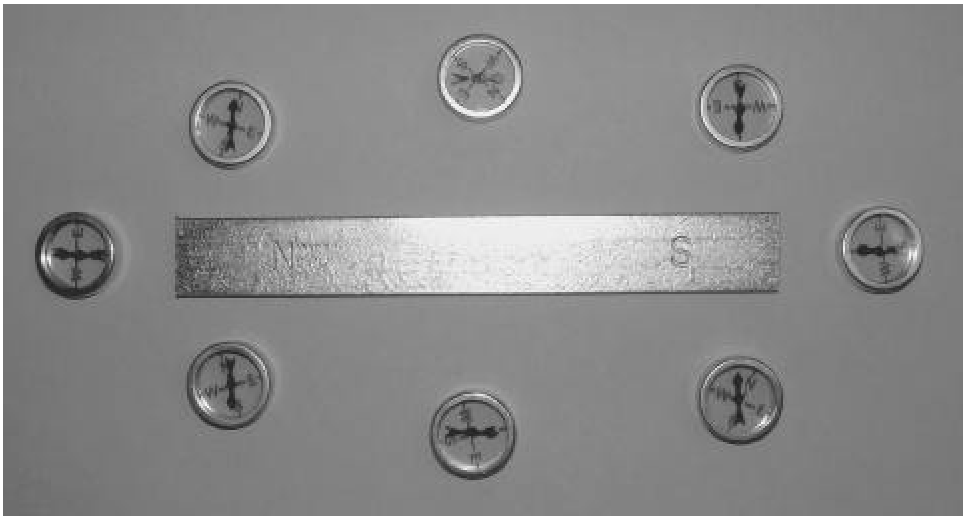


Figure 1.1 : Bar Magnet with magnetic compasses place around it. Note how the heads of the compass needles point toward the magnetic south pole and away from the magnetic north pole of the Bar Magnet.

4. Next you will have the students place the bar magnets on a piece of paper and have them trace the magnetic force field shape and direction with the compass. But first tell them what they will do and ask them to predict what they think the magnetic force field will look like (see worksheet 1.2).

   To make the tracings students start by placing the magnet on a piece of paper (or several pieces taped together to make a large surface area over which to draw).

   - Then they should draw a dot somewhere near the magnet and place the center of a compass over the dot.
   - From there they should draw a dot at the location of the arrow head of the compass needle.
   - Then they should move the compass center to this new dot, and again draw a dot at the location of the compass needle head.
   - Have them draw lines connecting the dots with arrows indicating the direction that the compass points.
   - The students should continue doing this until their line meets the magnet.
   - Then they should pick another spot near the magnet and repeat the process.

Have them continue until they have lines surrounding the magnet as shown in Figure 1.2. Have them do this for a single magnet first so they should end up with the dipole pattern of force field. Then, if time permits, have them place two magnets side by side and do the same thing again. Again if time permits, have them reconfigure the magnets once more. Be sure to ask the students to draw their predictions of what the field of force will look like before they determine its configuration with the compass and paper (see worksheet 1.2).

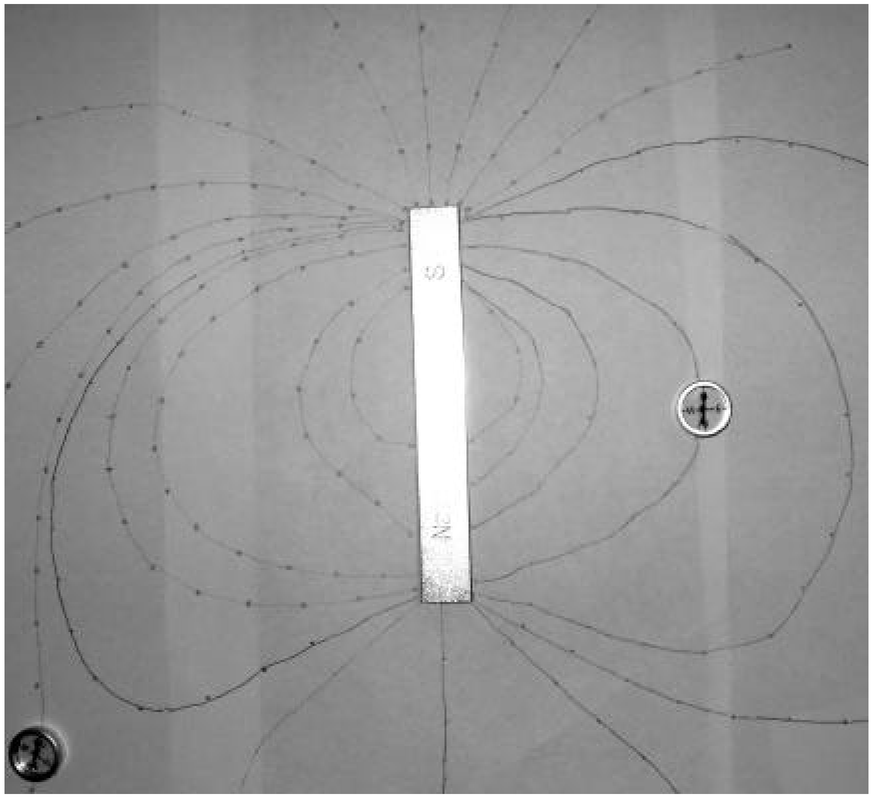
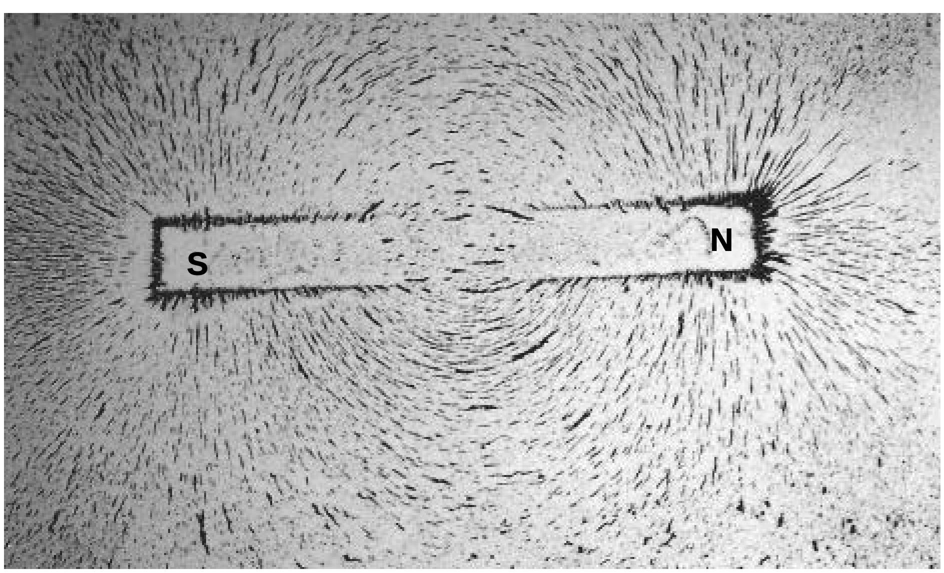


Figure 1.2: Magnetic Field line tracing of a bar magnet with compasses

[*The next step is optional. Or it could be demonstrated in front of the class by the teacher instead of by the students.*]



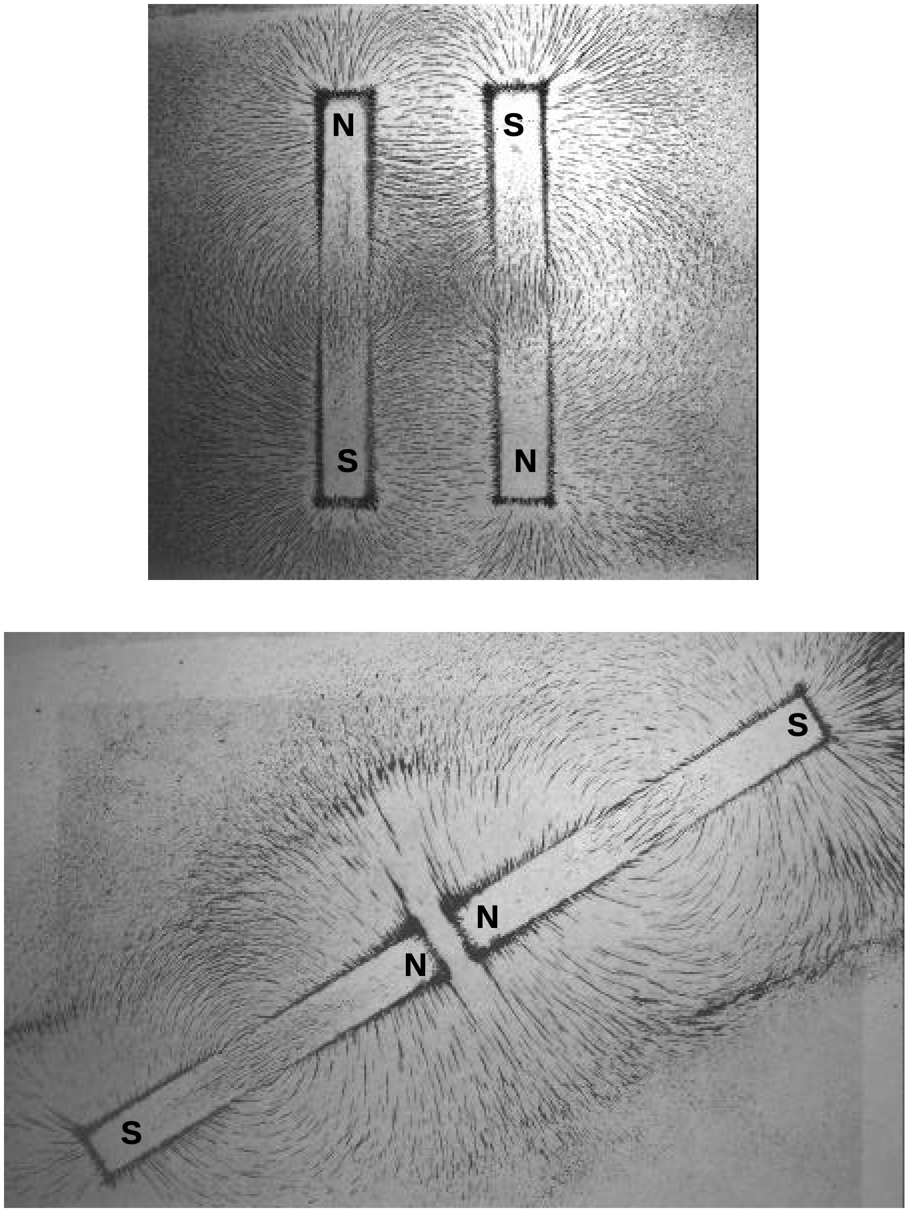


Figure 1.3: Iron filings on thin sheets of paper over bar magnets.

5. Students should be given iron filings and several thin sheets of paper. Then the students should place the paper on top of one of their bar magnets, lightly sprinkle the iron filings uniformly over the paper and then give the paper some taps/shakes so as to make the filings align with the magnetic field, as shown in the photographs in Figure 1.3. Students should record all their observations and the teacher should ask some probing questions to get the students to think about what they are seeing (see worksheet 1.3). The students should write down their answers to these questions. Can they explain what is happening? Have them form some ideas (hypotheses) about what could be the explanation for what they observe. Do they see the same shape as

they did with their compass tracings on paper around the bar magnets? If you haven't already spilled the beans about the filings acting like tiny magnets maybe now some students will be able to deduce this fact.

Next, lift up the paper carefully as to not spill any of the filings and funnel them back into your filings jar. Next, students should bring the second magnet next to the first in some configuration of their choosing. Students should predict what the magnetic field will look like and record a drawing of their prediction (see worksheet 1.3). Then place the paper on top of them and again sprinkle some iron filings over it. Tap/shake the paper to get the filings to align with the magnetic field. Such configurations can be seen in Figure 1.3. Now what do they see? Make sure they record their observations carefully by making drawings of their results and compare them to their predictions.

a) b)

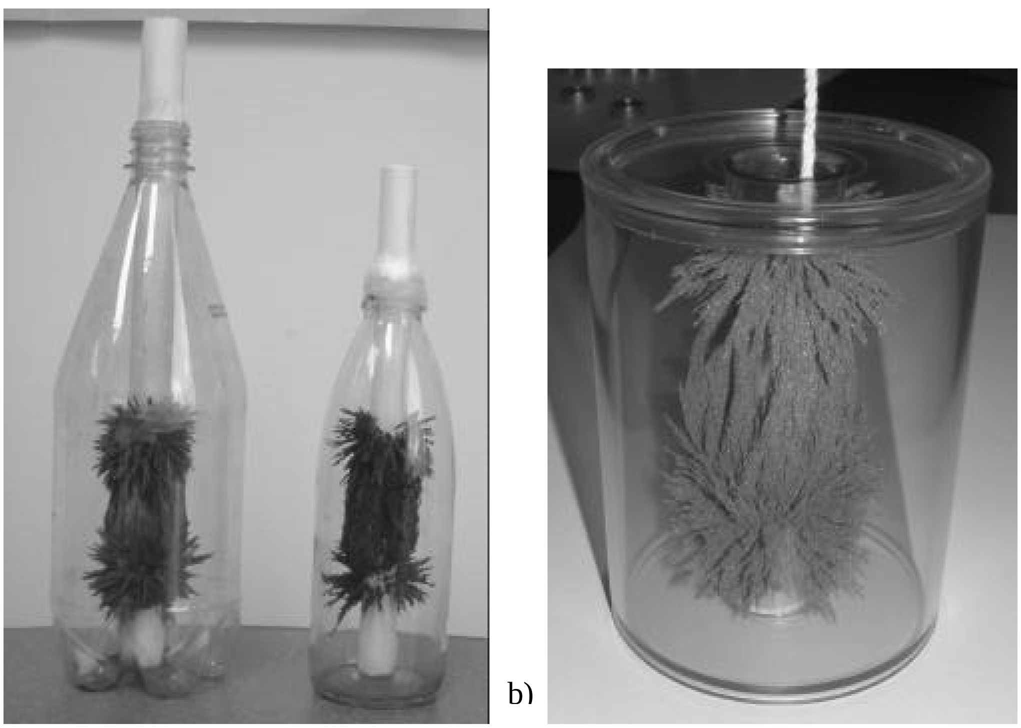


Figure 1.4: Visualizing the 3D magnetic field around a cow magnet using a 3D magnetic field visualizer a) made with simple materials, and b) purchased commercially.

6. For this step the teacher may simply do a demonstration for the class, or if you have enough materials, each group could build a 3D magnetic field visualizer. As the name suggests, you will construct (or buy if you have the funds) a device to visualize the 3D structure of a magnetic field around a cow magnet.

To construct your visualizer obtain a clear plastic or glass bottle, small/medium sized (i.e. a 20 oz. soda or water bottle). Clear away any labels on the bottle.

- Cut a manila folder so that you can roll it tightly up into a tube about the diameter of your cow magnet and a length slightly longer than your bottle. Tape the tube to keep it rolled up.
- Seal one end of the tube with tape and stuff some paper into that end so that when you insert the cow magnet into the tube it will not go all the way to the bottom of the tube.
- Pour some iron filings into the bottle, enough to coat the bottom with a layer ¼ inch thick should be fine.
- Insert the tube into the bottle and use paper and tape to seal up the bottle opening around the tube.

Now, drop your cow magnet into the tube. Use a pencil to hold it in place and then shake the bottle. The iron filings will then stick to the outside of the tube and take the form of the magnetic field surrounding the magnet. Have students predict the shape of the field before you actually do this.

You can remove the cow magnet by turning the bottle over and shaking it out (it will resist as the magnetic force of the filings will act to hold it in). Or you can fish it out of the tube by tying a string to a large paper clip and dropping it down into the tube and then pulling the magnet out. It's a neat effect to watch the filings be dragged up the tube until the magnet disappears and the filings drop away like dust. You can also purchase a pre-made, sealed tube with iron filings inside and a cow magnet for about $13 at most science classroom supply stores online (see resource list). For examples of the home-made tubes, see Figure 1.4a), and of a manufactured tube see Figure 1.4b).

An optional method of viewing the 3-D field of force surrounding a magnet is to fill a bottle with mineral oil and a couple of table spoons of iron filings. Seal the bottle and shake it up. As the filings begin settling place a magnet (the stronger the better, and cow magnets are stronger than bar magnets of the same size generally) against the side of the bottle. Hold the bottle up to the light and you will see the filings moving along the magnetic lines of force. You should be able to see full loops of force from one pole to the other. If you have a horse-shoe magnet (a bar magnet that has been bent into the shape of a horse shoe such that both poles are near each other) it can yield the most dramatic demonstration of the magnetic loops.

7. After completing the preceding activities the teacher should discuss with the class the observations made by the students and some of the ideas they have to explain them. Make sure to bring out the idea of like poles repelling and opposite poles attracting and that the magnetic force field has a direction. Also make note that the magnet would attract metals but not other kinds of materials. Perhaps bring out the idea that the iron filings were like tiny bar magnets that were aligning their poles with the attraction of opposite poles and repelling of like poles. Worksheets 1.1, 1.2, and 1.3 can be used as appropriate and you can develop your own question and answers.

Worksheet 1.1 for Measuring Magnetism

Name: ______________________________
Date: ______________________________

1. What do you notice about the interaction of the bar magnets you were given?

2. What materials interact with the magnets and how do they interact?

Interacts with magnets:	**Does not interact with magnet:**

What do all the materials that interact with the magnets have in common?

3. What happens when you bring a compass near a magnet? How does it depend on where you place the compass (use the back of this sheet if you need more space)?

Worksheet 1.2 for Measuring Magnetism

Name: ______________________________

Date: ______________________________

1. Draw what you predict the magnetic field will look around a single bar magnet. Include arrows that point in the direction the compass points north (red by convention).

2. Draw how it looks from your measurements with the compass.

3. Draw what you predict the magnetic field will look around two bar magnets in a configuration (or configurations) of your choice.

4. Draw how it looks from your measurements with the compass:

Worksheet 1.3 for Measuring Magnetism

Name: ______________________________

Date: ______________________________

1. What did you observe when you sprinkled the iron filings over the paper covering the bar magnet? Draw what you observed.

2. Can you explain why the iron filings did what they did?

3. Do you see the same trend as you did with the compass tracings?

4. Draw what you expect to see when you sprinkle iron filings over two bar magnets in a new configuration.

5. Draw what you did, in fact, see with your two magnets in the new configuration. How were your expectations the same or different?