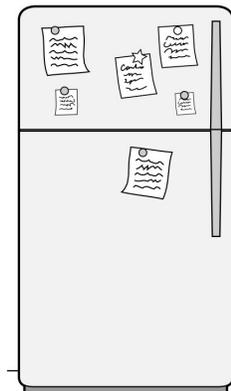


**Purpose and Materials Needed**

You are no doubt familiar with some magnetic phenomena, like using a magnet to hold paper on a refrigerator door, or using a compass to navigate. However, could you explain to someone else how these work? In this unit you will first investigate some phenomena involving magnets to establish their basic properties, and then develop a model that can explain your observations and be used to make predictions for new experiments.



*What are some properties of magnetic interactions?*

Your group's kit has the following materials that you will use for this lesson:

- ▶ Deep-dish bowl
- ▶ Disc of Styrofoam
- ▶ An envelope containing several items (See Table 1 below)
- ▶ Small magnetic compass
- ▶ Piece of tape
- ▶ Empty zippered plastic bag to use to empty the water in at the end of class
- ▶ In addition, your team should have a bottle of water

One member in your group should get a **bar magnet** and four small **disc magnets** (or a total of four bar magnets or four of any other type of magnet) from your instructor. Another group member should pick up three nails. Keep the nails far away from the magnets.

**When you get the magnets, keep them on the floor, far away from the nails and any other items in your kit, until you are directed to use it.**

## Predictions, Observations and Making Sense

### Part 1: How do magnets interact with other materials and with each other?

Do all types of objects show magnetic effects? That is, are all objects attracted to a magnet?

**CQ 2-1: What kinds of materials do you think are attracted to a magnet?**

- A. All materials, both metals (copper, aluminum, iron, brass, etc.) and non-metals (plastic, wood, glass, etc.)
- B. Only metals, but not non-metals
- C. Only non-metals, but not metals
- D. Only certain metals, not all metals
- E. Only certain metals and non-metals, but not all of them

To find out, lay the items listed in the table below (from your envelope) on a desktop. [If materials are not available, your instructor will show you a movie ([UM\\_L2\\_Mov1](#))] You will also need a plastic pen or plastic ruler. **[Only test one nail. Place other nails far away from the magnet.]** Bring the bar magnet near each. For each item, record in the table whether it is attracted (A) to the magnet, repelled (R) from the magnet, or if there is no effect (O). For each case, turn the magnet around and see if you get the same effect, or if something different happens (and if so, record that in the table). Add two other items of your own choice to the table and test them.

**Table I: Observations of Magnet near Objects (A, R or O)**

	Wood strip	Steel paper clip	Plastic pen or ruler	Aluminum strip	Iron nail	Copper wire	Nickel strip or wire		
Magnet									

Look over the data you recorded in Table I.



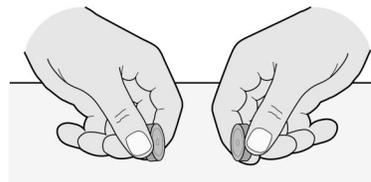
Does a magnet affect all objects? If not, which of the objects does a magnet affect?

 Does it make any difference which end of the magnet is used?

 Steel is an alloy (solid mixture) of iron and carbon<sup>1</sup>. Based on your observations, what kinds of materials seem to be affected by a magnet?

Scientists call materials that are attracted to a magnet, *ferromagnetic materials*. Iron is the most common ferromagnetic material, and objects or materials that include iron in them (like steel) are also ferromagnetic. (Nickel and cobalt are also examples of ferromagnetic materials.) Magnets themselves are also made of ferromagnetic materials.

Take the two small disk (or other types of) magnets in your hands and bring their faces (or ends) together slowly, but try not to let them touch each other.



 Describe what you feel as they approach each other.

Now turn one of the magnets around and bring them together again.

 Do they behave in the same way as before, or do you feel something different? If so, what?

When scientists study the natural world they focus their attention on different types of interactions between objects. When two objects interact they *act on* or *influence* each other in some way. In this course you will be studying many different types of interactions. The interactions you saw above, between two magnets, and also between a magnet and a ferromagnetic material, are examples of what we will call a *magnetic interaction*.

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<sup>1</sup> Stainless steel is an alloy of steel and chromium. There are two types, one of which is affected by magnets and the other is not.



How is the magnetic interaction between two magnets different from the magnetic interaction between a single magnet and a ferromagnetic material that is not itself a magnet?

When you are done, replace the items back into the envelope. Place the bar magnet and disc (or other) magnets back on the floor—far away from the other nails.

In the rest of this lesson, you will use iron (steel) nails to explore some important properties of the magnetic interaction.

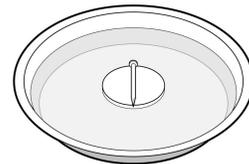
## Part 2: What happens when a nail is rubbed with a magnet?

In this experiment you will distinguish between two types of nails: those that are rubbed with a magnet (called *rubbed*), and those that are not rubbed with a magnet (called *unrubbed*). Initially all your nails should be *unrubbed*.

**Please keep the bar magnet far away from the iron nails until you are directed to use it. Once you rub a nail, it is no longer “unrubbed.” Please do not rub the nails until you are asked to do so.**

Your instructor will show you some movies ([UM\\_L2\\_Mov2](#) and [UM\\_L2\\_Mov3](#)) of how you should carry out the following explorations. It is important that everyone follows the same procedure. Below are instructions that you may refer to after the movies.

To make a sensitive detector, place the dish on the table with enough water in it to fill it to a depth of about one-half inch. Place the small float in the water and put one of the **unrubbed** nails on it. The nail



may stick out more than the one shown here in the figure. (If it does not float freely you may need to add a little more water to the dish.)

Now make a **rubbed** nail as follows. Far away from the floating nail, pick up a second **unrubbed** nail and hold it horizontally at its head end. (The end you would hit with a hammer.) Pick up the bar magnet, hold it at right angles to the nail and slide one end of the magnet (either end is OK) **all the way from the head to the point end of**

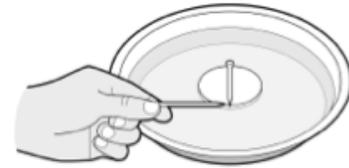


**the nail.** Then lift up the bar magnet and repeat this a few more times, always sliding it in the same direction (**not** back and forth).

Record here which Pole of the magnet (N or S) you used to touch and slide across the nail from head to tip: \_\_\_\_\_

*After you have rubbed the nail, be sure to place the magnet back on the floor.*

You will now investigate how this rubbed nail interacts with the floating unrubbed nail by doing the following. Hold the rubbed nail horizontally in your hand, and bring its tip **close to** (but not touching) the floating unrubbed nail. See picture to the right showing that the held nail should be **horizontal** (just above and parallel to the surface of the water) and at **right angles** to the floating nail.



Always test held and floating nails this way. Do not bring the held nail downward from above (picture below to the left), and do not bring it parallel to the floating nail (see picture below to the right).

**Do NOT do it this way (from above)**



**Do NOT do it this way (parallel)**



 What, if anything, happens to the tip of the floating unrubbed nail? Is it attracted (A), repelled (R), or does it show no reaction (O)? Record your observation in the appropriate box in Table II below.

 Next, bring the point end of the rubbed nail near the head end of the unrubbed nail and record your observations in Table II.

 Finally, bring the head end of the rubbed nail near the point end of the unrubbed nail, and then bring it near the head end of the unrubbed nail. Record both observations in Table II.

[Your instructor may show you a movie ([UM\\_L2\\_Mov4](#)) of these effects. ]

**Table II: Interactions between Rubbed and Unrubbed Nails (A, R or O)**

	Point end of <b>unrubbed</b> nail	Head end of <b>unrubbed</b> nail
Point end of (held) magnet-rubbed nail		
Head end of (held) magnet-rubbed nail		

 Do the two ends of the **unrubbed nail** behave the same way or differently when each end of the magnet-rubbed nail is brought nearby?

Lay the rubbed nail aside for a moment. *Imagine* that you removed the floating nail, rubbed it with the magnet in **exactly the same way** that you rubbed the other nail, and then floated it again. (**DON'T DO IT YET!**) You would then have two rubbed nails – one held and one floating.

 Predict what you think would happen if you were to bring the tip of the held **rubbed** nail near the tip of the floating **rubbed** nail.



Predict what you think would happen if you were to bring the tip of the held **rubbed** nail near the head of the floating **rubbed** nail.

Now remove the floating nail, rub it with the magnet using the **same end** of the magnet you used previously, and replace it on the floater. Then test your predictions.



Repeat the same set of four tests that you did in STEP 3 with the two rubbed nails. Record your observations in Table III below. [Your instructor may show you a movie ([UM\\_L2\\_Mov5](#)) of these effects.]

**Table III: Interactions between Two Rubbed Nails (A, R or O)**

	Point end of (floating) <b>magnet-rubbed</b> nail	Head end of (floating) <b>magnet-rubbed</b> nail
Point end of (held) magnet-rubbed nail		
Head end of (held) magnet-rubbed nail		



Do the two ends of the magnet-rubbed floating nail behave the same way or differently when each end of the magnet-rubbed nail is brought nearby?



Based on your observations, would you claim that rubbing a nail in the way you did turned it into a magnet, or does it still behave like a ferromagnetic material that is not itself a magnet? What evidence supports your answer?

When a nail (or any other object made of a ferromagnetic material) is rubbed with a magnet and behaves in the same way as you observed above, we say it is *magnetized*. Therefore, from now on we will refer to a 'rubbed nail' as a 'magnetized nail,' and an 'unrubbed nail' as an 'unmagnetized nail.'

Some magnetized objects retain their magnetism for very long periods of time, and we call them *permanent magnets*. The bar magnet you are using is probably made from alnico, an alloy of iron with **al**uminum, **n**ickel and **co**balt, that is a good permanent magnet. Other ferromagnetic materials, which tend to lose their magnetism easily after being magnetized are sometimes called *temporary magnets*.

Suppose you were to touch a magnetized nail all over with your fingers.



Do you think the nail would still be magnetized after you did this, or would it act more like an unmagnetized nail now? Why do you think so?

Now test your thinking by touching one of your magnetized nails all over with your fingers. Place it on the float and test its ends with your second magnetized nail.



Was the nail still magnetized after you touched it all over or not?



Now suppose you dropped a magnetized nail in water. Do you think the nail would still be magnetized after you did this, or not? Why do you think so?

Again, test your thinking by dropping one of your magnetized nails in your pan of water. Then place it on the float and test its ends with another magnetized nail.



Was the nail still magnetized after it was immersed in water, or not?

Your instructor will review the observations with the class and may show a movie ([UM\\_L2\\_Mov6](#)) of the effects.

### Part 3: How are the ends of magnets and magnetized objects labeled?

Place a **magnetized** nail on the floater, making sure the other rubbed nail and the bar magnet are far away. [If your chair or table has steel legs or supports, they may affect the following observation. In that case, you should try to keep the dish away from the steel by moving it to a different part of the chair top or table, or just holding the dish in the air.] Now do the following a few times. (You may have to wait up to a half a minute or so each time for the nail to settle into a stable position.)

- Aim the floating nail in different directions in the middle of the pan, then release it and wait until it settles into a stable position. (Make sure the floater does not get 'stuck' against the side of the pan while this is happening.)
- Spin the floating rubbed nail gently, and again wait until it settles into a stable position.

Your instructor will point out the approximate directions for north, south, east and west, and may show a movie ([UM\\_L2\\_Mov7](#)) of the effect if materials are not available



Does the floating magnetized nail end up pointing in a different direction each time, or does it always seem to end up pointing in the same direction? If so, in which direction does the pointed end of the nail seem to 'want' to point?

**CQ 2-2: Which direction is the point end of your group's magnet-rubbed nail pointing after it settles down?**

- A. North
- B. East
- C. South
- D. West

Whenever a rubbed nail, or any magnet, is allowed to rotate freely, without another magnet nearby, one end will always end up pointing (approximately) towards the geographical North Pole of the Earth. By mutual agreement, scientists **define** this end of the magnet as the *north-seeking pole* (or N-pole for short) of the magnet. The opposite end of the magnet, by definition, is called the *south-seeking pole* (S-pole). (Your bar magnet may already have its ends labeled as N and S to signify this.) Thus, when you rub your nail you turn it into a magnet with a N-pole and a S-pole.

 Is the tip (pointed) end of your group's floating magnetized nail a N-Pole or a S-Pole? What about the head end?

In your kit you should also have a small magnetic compass. Take it out and place it on the palm of your hand, holding it far away from the magnet and the magnet-rubbed nails. The needle in the compass is made of a special ferromagnetic material that has been magnetized and retains its properties for a long time; i.e. it is a small permanent magnet.



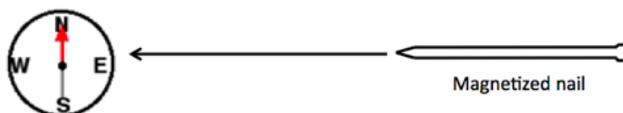
The compass needle is free to pivot, and so one end of the needle will always point towards geographic north—and by definition, that is the N-pole of the compass needle. (Notice that, in effect, your floating magnetized nail is also a compass needle.)

 Which end of **your** compass needle is a N-pole, the colored tip or the uncolored tip? (Do not rely on the labels on the compass itself. Instead, use the directions above to help you. Other groups' compasses may be different from yours.)

#### **Part 4: How do the poles of two magnets interact with each other?**

Lay your compass on the table and rotate it so that the N-pole end of the compass needle is aligned with the “N” marking (for the North direction) on the casing of the compass (as in the picture above).

Lay one of your magnetized nails on the table with its N-pole pointing towards the “E” (for East) label on the compass, and then slide it towards the compass, as shown in the picture below. [Note: Your magnetized nail may have its N-pole at its head end, in which case you would slide its head end toward the compass.]



- 🔍 What happens to the N-pole of the compass needle? Is it attracted to or repelled by the N-pole of the nail?

Move your magnetized nail away from the compass and turn it around so that its S-pole faces the E-label of the compass. Now slide it towards the compass again.

- 🔍 What happens to the N-pole of the compass needle now? What about the S-pole of the compass needle?

- 🧩 Do like poles (N-N or S-S) of the magnetized nail and compass needle attract or repel each other? Do unlike Poles (N-S, or S-N) attract or repel each other?

Check your conclusions with at least one other group to make sure you all agree. If not, repeat the observations. Your instructor may also show a movie ([UM\\_L2\\_Mov8](#)) of the effects.

Your statement about how like and unlike Poles interact with each other is known as the *Law of Magnetic Poles*.

As you have seen in this lesson, the two ends of a magnetized nail behave differently when near another magnetized nail. Because of this property, we say that a magnetized nail is '*two-ended*.' On the other hand, since both ends of the unmagnetized nail behave the same when near another magnetized nail, we say that it is '*one-ended*.'

## Summarizing Questions

- S1:** An elementary school student asks you for advice about a science project she is doing on recycling. She suggests that a large permanent magnet could be used to separate metals from non-metals in the trash passing through a recycling station. What do you think of this idea?
- S2:** In this activity you magnetized a nail by rubbing its surface with a magnet. Do you think that whatever causes a nail to be magnetic also lies on its surface, or inside the nail? What evidence supports your thinking?