MAGNETISM

PROBLEM PRESENTATION / EXPLORATION

A. What is Attracted to a Magnet?

1. According to legend the discovery of magnetism occurred about 3000 years ago in an ancient Middle Eastern country called Magnesia (it is a part of modern day Turkey). Here special rocks known as lodestones were found to be naturally attracted to certain other objects. Since that time we have found ways to alter substances that do not naturally possess this property, so that they too can exhibit the same mysterious ability found in the ancient lodestone.
2. Assemble a collection of objects including samples of wood, metals, liquids, rubber, cloth, plastics, and any samples of elements (iron, gold, silver, aluminum, etc.). Also include a penny, nickel, and dime. Make sure that for some groups of students you put out an American 5¢ piece and other stations put out a Canadian 5¢ piece. Test each with a lodestone or with a magnet. Which substances were affected by the magnet?
3. Where on the magnet did the attraction seem to occur? Investigate other magnets with different shapes. Determine which portions of each magnet exhibit the attractive properties.

B. What Materials Will Magnetism Pass Through?

1. Tie some string to a powerful horseshoe magnet and suspend it from a ring attached to a ring stand.
2. Tie some thread to a paper clip. Adjust the length of the thread so that when it is taped to the table top it will extend to a length so that the paper clip will be attracted to the magnet. It will appear to be floating in mid air. There should be about 3 cm between the top of the paper clip and the bottom of the magnet.
3. Use this set up to reinforce the idea that there is an invisible force acting on the paper clip coming from the magnet. Ask the class what would happen if the string were cut. Will another invisible force called gravity be stronger than the magnetic force? Just so that everybody is sure, go ahead and cut it.
4. Obviously magnetism passes through air as illustrated by the floating paper clip. But through what other substances will it pass? Before testing any substance, force the students to predict what they think will happen.
    a. Start with putting a piece of paper between the magnet and the paper clip. Does the paper clip still float? Does this mean that the magnetic force can pass through one sheet of paper? [Yes]
    b. Try a piece of cardboard.
    c. Try a piece of glass.
    d. Try a piece of plastic (overhead transparency is good, or one of those plastic covers than comes on a can of coffee).
    e. Try a piece of aluminum foil.
    f. Try a piece of thin wood.
    g. Try a thicker piece of wood.
    h. Try water. (A good way to do this would be to put some water in the plastic coffee lid.)
    i. The strength of your magnet will ultimately determine how many of these substances allow the magnetic force to pass through.

C. Can You See Magnetism?

1. We have said that the magnetic attraction that magnets have for objects containing iron, cobalt, or nickel is thought of in terms of a magnetic force. So far we have only seen the results of this force. How can we see how this force is oriented around the magnet?
2. Sprinkle iron filings on a plate of glass, a piece of cardboard, or on a paper plate. Place this over various shaped magnets. It works better if the glass is very close to the magnet but not resting on it. One way to accomplish this

would be to put a rubber stopper at each corner of the piece of glass. The stoppers serve as legs to keep the glass up off the magnet.

3. Tap the glass gently so that the filings are evenly distributed and so that they can align themselves along the lines of magnetic force. In this way we can "see" the magnetic force around each magnet.
4. Compare what this reveals with what you found out concerning the sections of a magnet that seems to attract metal objects. [The greater the concentration of the magnetic force lines, the greater the attractive power of the magnet.]
5. Place under the glass two magnets. First arrange them so that unlike poles are near each other, then arrange them so that like poles are near each other. How do the patterns of iron filings differ?
6. Lest students think that magnetic lines of force only operate in the plane of the glass plate, a three dimensional version of this exercise can be conducted.
   a. Get a bottle of cooking oil. A cylindrical bottle works best. Add directly to the bottle a handful of iron filings. Replace the cap, if it is metallic, with a plastic one, or put a rubber stopper into the mouth.
   b. With the bottle tightly capped shake the iron filings and oil. Place a bar magnet next to the bottle. Wait at least two minutes for the alignment to take place. Try putting the magnet perpendicular to the long axis of the bottle. Then try aligning the long axis of the magnet with the long axis of the bottle. You will be able to see that the lines of force go out in all directions, not just in one plane.
   c. Fix two bottles with iron filings. Place them side by side. Suspend the bar magnet between the two bottles. This will allow a full set of magnetic force lines to develop.

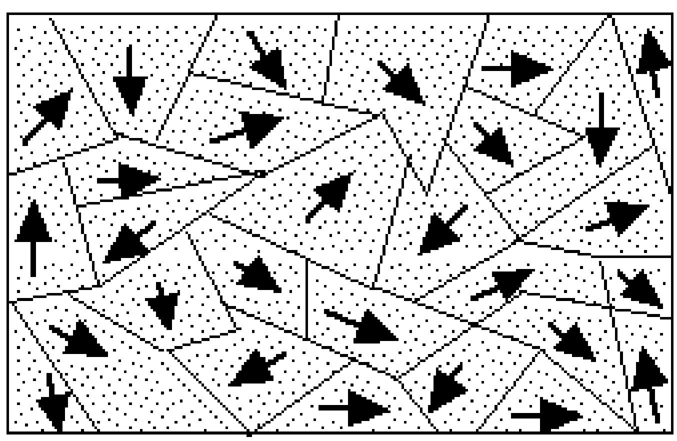
CLASS RESPONSE / CONCEPT INVENTION

A. How Can Magnets Be Made?
   1. Temporary magnets (needle)
      a. Hold a needle by its eye end and rub its entire length on one end of a strong magnet about 30 times, from the eye to the point only.
      b. Set a bowl far from any iron or steel objects. Pour in some water and float on it a piece of aluminum foil as large as a quarter.
      c. Lay the magnetized needle on the foil. What does it do? If it is spun around, does it return to the same position each time? [Yes]
      d. The end of the needle that is pointing toward north is called the north-seeking pole. (It actually is the south pole of the needle.) Mark this end of the needle with some red finger nail polish.
      e. Put someone else's floating needle in your bowl. What happens when the two north-seeking poles come close together? What happens when the two south-seeking poles come close together? What happens when opposite poles come together?
   2. Temporary magnets (crowbar)
      a. If we tried to rub a crowbar in the same manner as the needle, it would not work very well. A very powerful magnet would be required as well as a lot of rubbing. But there is an easy way to magnetize a crowbar.
      b. Start by facing north and point the crowbar downward at about a 25° angle.
      c. With a hammer, gently tap the end of the crowbar which is nearer to you. Tap for about one minute.
      d. Try to pick up some paper clips with the end of the crowbar which is farther from you.
      e. Now turn and face east and hit the crowbar with the hammer for about a minute
      f. Again try to pick up some paper clips. What has happened? [The

crowbar should no longer act as a magnet.]

B. Why Do Magnets Work?

1. Only a small number of substances can be used to make magnets. Iron, cobalt, and nickel are the best materials with which to make a magnet.
2. Apparently, stroking these materials with a permanent magnet somehow rearranges the particles of matter in some way to cause the magnetic property to appear.
3. Clumps of iron atoms in the needle called **domains** are themselves little magnets. They have a north pole and a south pole. However these domains are not arranged in such a way as to make the needle magnetic until the permanent magnet acts on them. The permanent magnet aligns them so that all the north poles are facing the same direction (all the south poles would have to be pointing in the opposite direction.) This aligning is what causes the overall effect by having each tiny little magnetic field add together to produce the new magnetized needle. When the domains were randomly arranged they tended to cancel one another out and the metal did not behave like a magnet. This outside influence of the permanent magnet is called induction, similar to what we saw happen when we charged an electroscope by induction in the Static Electricity lesson. The larger question is why can some materials be magnetized while others can not. The reason that the individual domains and the even smaller atoms of which they are made up have a north and south pole can be traced to the motion of the electrons in the atoms. Specifically, it is the spin of the electrons that is responsible. In most elements the electrons occur in pairs in the individual atoms. Each electron is spinning in the opposite direction of its paired electron. This spinning of the negatively charged electron creates a magnetic field. Because of the opposite spins the magnetic fields are canceled out. Some metals, however, contain atoms with unpaired electrons. Since these weak magnetic fields have not been canceled out by the electrons being paired, each atom has a weak magnetic field. The individual magnetic fields extend in many different directions in an unmagnetized substance. Not until a strong magnet comes close to the metal will these randomly dispersed magnetic domains arrange themselves in the same direction to form a temporary magnet.



4. Why does a paper clip attracted to a permanent magnet attract another paper clip to it? [Temporarily the permanent magnet induces, or lines up the domains in the first paper clip, so that it acts as a very temporary magnet. When the first paper clip is removed from the permanent magnet it loses its ability to attract other paper clips. The domains in the first paper clip move back into their random orientation when the permanent magnet is removed.]
5. How con we explain the magnetizing and demagnetizing of the crowbar?

[Hitting the crowbar as it was aligned with the biggest magnet known (the earth) moves the domains in the crowbar to line up with the magnetic forces lines coming out of the north pole of the planet. Pointing the crowbar east and west and hitting it with the hammer disrupts the domains and the crowbar loses it magnetic properties.

6. Heat the magnetized needle in a Bunsen burner flame for a minute. After allowing it to cool test out its magnetic properties. Why does it no longer act as a magnet? [The heat disrupts the alignment of the domains.]
7. The temperature at which the iron loses its magnetic property is know as the Curie point. Pierre Curie discovered in 1895 that the temperature at which the domains are disrupted varies for different metals. The Curie point for iron is 768°C, for cobalt 1100°C, and for nickel 375°C.
8. Experimentally determine the Curie point for a Canadian nickel minted before 1982.
   a. Unknown to the students mix in at least one Canadian nickel minted before 1982 with other US nickels. Ask the students what will happen when a magnet is put into the pile of nickels.
   b. Probably they will respond that nickels aren't attracted to magnets. This is true for US nickels since they are only 25% nickel. But for the Canadian nickel minted before 1982, there is enough nickel metal that it will be attracted to the magnet.
   c. With a magnet adhering to the Canadian nickel move it into the flame of a candle. Note what happens after the nickel has been sufficiently heated (>375°C). [The nickel will fall off the magnet since the Curie point has been exceeded and the nickel is no longer magnetic.]
9. What is the biggest magnet you have ever seen?
   a. Probably planet Earth is the correct answer to this question, but what is the largest magnet that you can see in its entirety?
   b. To almost everyone's surprise it is found inside the house. Not every house contains one. The older the house, the better chance that it will contain this magnet. Give up?? It is in the bathroom. That's right, it is the bathtub. As mentioned above not every house has one. None of the modern day bathtubs work because they are made out of fiber glass. Even if your house has a metal bathtub it might not qualify for being a magnet.
   c. In old, old houses where the bathtubs were made out of cast iron you will find your magnets. Because it has been in the same location and orientation to the magnetic field of the earth, for a long period of time, many of these old bathtubs have undergone alignment and are magnetic. If the tub is in a north-south direction in the room, one end will be north and the other south when a compass is brought near. This applies to the Southern states. In states farther north, the north and south points are likely to be at the top and bottom of the tub.

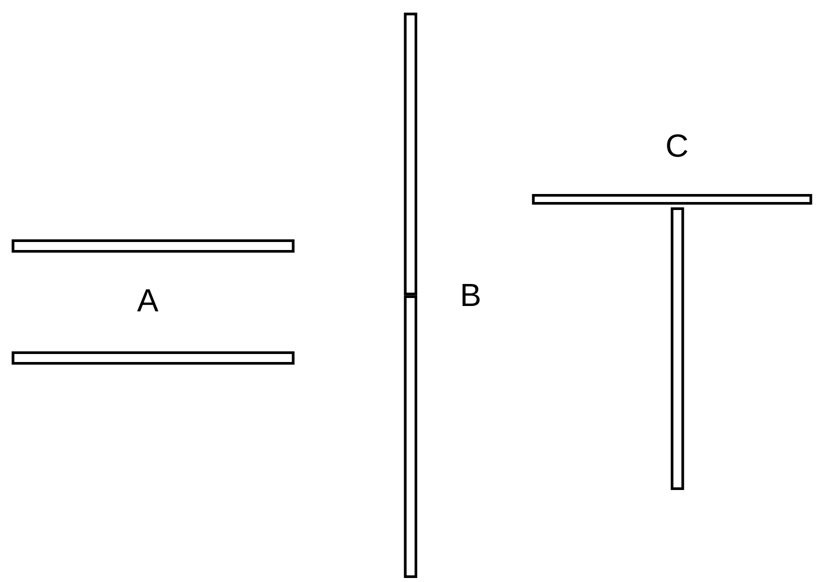
CONCEPT EXTENSION

A. Cutting Up a Magnet
1. What would happen to a bar magnet if you cut it into three equal pieces with a hacksaw?
2. It turns out that unless you have a very good hacksaw or a very lousy bar magnet that it is very hard to saw the magnet into three pieces. An acceptable substitute for this exercise is to magnetize a needle. The needle can be divided into three equal pieces much easier.
3. Predict what will happen when you put the three pieces back together in the same order as they were before cutting. [All three pieces will attract each other.]

4. Pull the two ends away from the middle. Turn them around so that what were the north and south poles of the unsawed magnet are now pointing inward toward the center piece. Move them toward the center piece. Predict what will happen. [The center piece repels each end piece.]

5. Separate each of the three pieces of the magnet and test each end with a paper clip. [Each end of each magnet should attract the paper clip.]
6. Using all these observations explain what happens to a magnet when it is cut or broken. [When the magnet is cut the cut end becomes the opposite pole to the that of the other end of this piece. This would account for the two end pieces. The middle piece in turn will have a north end (the end that was originally attached to the top piece) and a south end (the end that was originally attached to the bottom piece.)
7. A magnet that is cut in two does retain its magnetic power, but the vibrating experienced when it was sawed apart weakens it considerably.
8. What would you predict if the magnet was cut in half along its long axis? How would the two pieces react to each other and to a paper clip? [The left half would be repelled from the right half. Both halves would still act as magnets. The top half of the left side would repel the top half of the right side. It would be very difficult to glue the two halves back together.

B. Which Bar is the Magnet?
1. Two identical steel bars are needed for this problem. One should be a bar magnet while the other should be unmagnetized.
2. Propose to the students the following problem: One of these bars is a magnet and one isn't. Without using any other materials how can we tell which one is the magnet." Encourage them to apply the ideas learned in the other parts of this lesson.
3. If they run out of ideas, suggest placing the bars in the following positions, A, B, and C and have them evaluate what happens. Only in position C will they be able to deduce which bar is the magnet.



4. In A the two bars will be attracted to each other but we will not be able to tell which one is doing the attracting and which one is being attracted. In B the two bars will also be attracted to each other, but again we will not know which one is the bar doing the attracting.
5. Why will setup C allow us to figure out which bar is the magnet? Thinking back to what we learned about the magnetic field about a single bar magnet we know that the field is weakest at the center of the bar. If the horizontal bar is the magnet, there will be no attraction. If the horizontal bar is not the magnet, there will be attraction because the pole of the magnet will be attracted all up and down the unmagnetized bar.

C. The Compass in Your Nose

1. "All humans have a trace amount of iron in their noses, a rudimentary compass found in the ethmoid bone (between the eyes) to help in directional finding relative to the earth's magnetic field.

   Studies show that many people have the ability to use these magnetic deposits to orient themselves--even when blindfolded and removed from such external clues as sunlight--to within a few degrees of the North Pole, exactly as a compass does.

   A researcher from England's Manchester University found that when a magnet is placed on the right side of the head, the directional accuracy of test subjects falls 90 degrees to the right. When a magnet is placed on the left side, the error falls 90 degrees to the left, proving conclusively that humans are profoundly affected by magnetic fields.

   Though no one knows how this 'sixth' sense is processed by the brain, more than two dozen animals, including the dolphin, tuna, salmon, salamander, pigeon, and honeybee, have been found to have similar magnetic deposits in their brains to help them in navigation and migration." {McCutcheon, M, (1989). *The Compass in Your Nose and Other Astonishing Facts About Humans*, Jeremy P. Tarcher, Inc., Los Angeles, pp. 96,97.}

2. Have the class organize an experiment using their own members to see if there is anything to this ability to orient ourselves with respect to magnetic north without a traditional compass. There are a number of things that must be controlled to make any conclusions valid.