Magnetic Fields Inquiry — Teacher's Notes

Main Topic	Magnetism
Subtopic	Magnetic Fields
Learning Level	High
Technology Level	Low
Activity Type	Student

Description: Experiment with magnetic fields and electromagnetism in an inquiry exercise.

Required Equipment	Bar magnet pair (2), poster board, compass, ruler, D battery (2), battery holder (2), magnet wire, Lenz's Law Apparatus, magnetic field viewer paper, plastic tube, galvanometer.
Optional Equipment	

Educational Objectives

- Observe the shape of magnetic field lines.
- Observe the effect of distance and number of magnets on field strength.
- Observe the effect of eddy currents.
- Construct a simple generator and relate it to the operation of a motor.

Concept Overview

We will explore *magnetic field* configurations and *field strengths* for permanent magnets in this inquiry exercise. Students will observe the curved field lines around a permanent magnet, and explore how field strength varies with distance. They will observe the magnetic field created by a current-carrying wire, as well as the current created in a wire when a magnet moves past it.

Lab Tips

This lab may take multiple lab periods.

Acknowledgement

Adapted from "Tesla's Domain: Magnetic Fields," an Inquiry Exercise by J. R. Harkay. See www.PhenomenalPhysics.com for more information on the complete Guided Inquiry Curriculum.

Magnetic Fields Inquiry Name: ___________________
Class: ____________________

Materials:

Bar magnet pair (2), poster board, compass, ruler, D battery (2), battery holder (2), magnet wire, Lenz's Law Apparatus, magnetic field viewer paper, plastic tube, galvanometer.

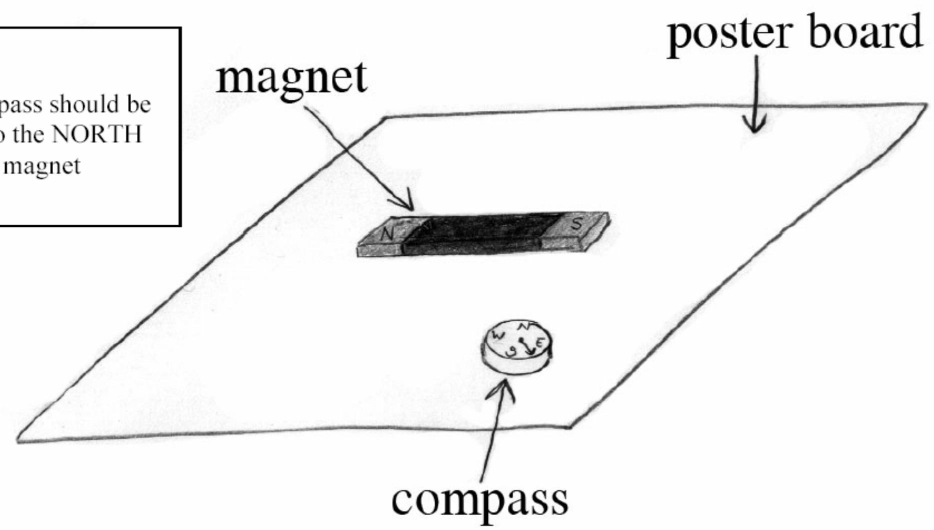
Commentary:

We will explore *magnetic field* configurations and *field strengths* for permanent magnets in this exercise. We will use: a strong bar magnet, several smaller "stackable" magnets, a small compass, a battery in a holder, a piece of wire, a sheet of poster board, and a ruler. If one is available, a thick-walled copper pipe and a neodymium magnet.

Inquiry:

1. Choose a horizontal workspace that is as free as possible from stray magnetic fields or steel. Place a strong bar magnet on the poster board. Make sure that the north pole points toward one end of the poster board and the south towards the other. (See illustration.) Avoid placing the magnet on the poster board in such a way that the poles are on the top and bottom of the magnet, or you will get nonsense. (Some rectangular magnets have their poles on the large flat sides, rather than the ends.)

NOTE:
Your compass should be pointing to the NORTH end of the magnet



   a. Place a small compass next to one corner of the magnet. The needle should point toward the magnet pole. Make a dot on the posterboard near the back end of the needle, and another near the front end of the needle.
   b. Now move the compass away from the magnet, so the dot which was at the front is now at the back. Make a new dot at the front.
   c. Repeat this process until you return to the magnet again. Drawing a curve through the dots should yield a "loop" in the magnetic field, or points for which the field has equal strength (like a topographic map). This line is sometimes called a "line of force" and is a tool used to visualize fields.
   d. The lines are referred to as "imaginary." You can see yours, though. What have you done to make it "visible"?

e. Start at several points over the magnet to trace out several loops (at least six for each end, or pole.) Does the field look as you expected?

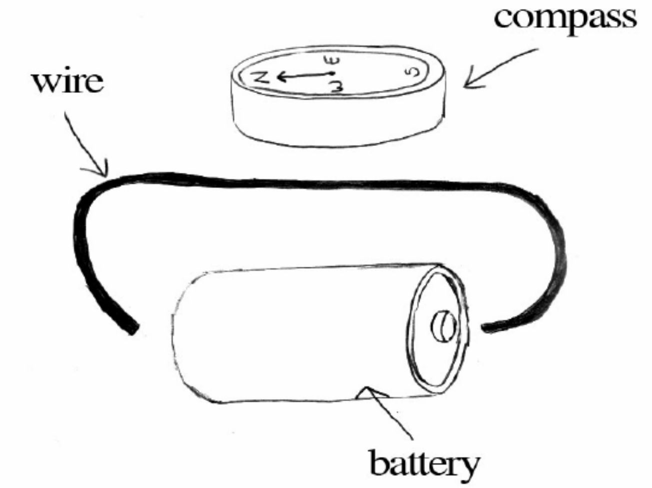
f. If there were any unexpected deviations from your prediction(s), how might you explain them? Can you infer what the field looks like for the other side or end using symmetry?

2. If you have several magnets, you can explore field strength as a function of the number of magnets and the distance from a magnet. When using multiple magnets, be sure to stack them so they reinforce one another, south pole to north pole, etc…. Experiment with varying the number of magnets and varying the distance between the compass and a magnet or magnets.
   a. Begin with a single magnet. Place the compass on a surface in a manner that the needle points in a direction which is perpendicular to the north-south axis of the magnet. For example, if the compass normally points from S to N, place a magnet in an E-W orientation. The original orientation of the compass needle is due to the Earth's magnetic field. We want the field due to the magnet to act at right angles to this so by looking at the angle from North, we can estimate the relative strength of the magnetic field due to the permanent magnet as compared to the earth's field.
   b. If the distance from the compass to the pole of the magnet or magnets is doubled, how many magnets are required to turn it from its original position through the same angle?

   c. What if the distance is tripled?

   d. Now, place a single magnet perpendicular to the axis of the compass again so that the needle is deflected by an angle of about 5-10 degrees. Add magnets in a stack and record the angle of deflection as a function of the number of magnets. Is the angle proportional to the number of magnets? If not, can you explain why not? (Think about why the magnet is pointing in its original direction.)

3. Finally, place the compass next to a horizontal wire that is carrying a current (the wire will have to be connected to a power source like a flashlight battery.) Only leave the wire connected long enough to see what happens and disconnect immediately afterward. NEVER try this with a wall outlet! You can use the connection to the battery as a switch. The compass needle should point parallel to the wire when no current flows if you have it oriented correctly. Your instructor will help you to find a way to vary the current in the wire if you are to do so.



   a. Keep the current fixed and slowly move the compass away from the wire. You must hold the compass steady in the vicinity of the wire. Placing the compass on a book so the edge of the compass is near or touching the wire may help. How does the angle vary with distance from the vertical wire? Do you a similar dependence of angle on distance for a permanent magnet?

   b. Holding the distance constant, does the compass angle change if you add another battery in series with the first? If so, what changes occurred?

   c. (Optional:) How does the angle that the compass needle makes vary with current? (You must have the ability to do this and measure the current.) This time, hold the distance from the wire to the compass constant.

4. If you have access to a strong neodymium magnet and metal tubes, try this. Now that we have seen that electric currents (not static electricity) can create magnetic fields, let's see if magnetic fields can do anything.
    a. Drop a marble or pencil or any non-magnetic object down the tube and let it fall out the other end. Record what happens.

    b. Next, drop a SINGLE neodymium "supermagnet" down the pipe and record what happens.

    c. Try moving the magnet along the outside of the tube and drop it close to the outside and record your observations.

    d. Take a guess at an explanation as to why you see the enormous difference between the situations above and record it.

    e. Next, if one is provided, place the green field viewing strip on the side of the pipe and let the magnet drop again. See anything interesting? Think about what it takes for an object to reach terminal velocity.

    f. Now stack two magnets together (carefully!). You've made it heavier, right? See what happens and record your result. Which goes faster—one magnet or two?

    g. Okay, so you haven't entirely figured this out yet. Let's go one step further. If you have one, drop your magnet down the inside of a *nonmetallic* pipe that has wire wrapped around it and a means of measuring electric current (light bulb, LED, or meter). What do you detect now?

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h. Try this with BOTH pipes: instead of dropping the magnet, tie a string to it or suspend it from a piece of tape and hold it inside the pipe. Does anything happen? Why or why not? Try moving it up and down slowly and then fast. Does anything happen now?

i. Now explain fully why the magnet falls so slowly when it is inside the pipe!

j. We have seen that electric currents create magnetic fields. We also looked at symmetry on nature early on. Is it fair to say that constant magnetic fields create electric currents? Alternatively, must the fields be changing?

k. What you have really done with the magnet and pipe is to create a generator. Electric currents create magnetic fields and magnets repel. That is the underlying principle behind the motor. If we instead move a magnet around inside a coil of wire, the changing field causes a current to flow. In other words it generates electricity. The symmetry is preserved and we can now think of electricity and magnetism as not two different phenomena but a single one called electromagnetism. It wasn't until the end of the Nineteenth Century that scientists came to understand this.
l. Make a simplified sketch of how YOU would build a motor and a generator.