

**Goal:** To investigate the phenomenon of magnetism by plotting the magnetic field lines around various types of magnets.

**Equipment:**

<u>Part A</u>	<u>Part C</u>
Lucite square	various magnets
bar magnet	iron grains
2 small compasses	Lucite square
air table paper	Compass
large box	

**Prelab:** Read Walker 22.1 and be prepared to answer these questions:

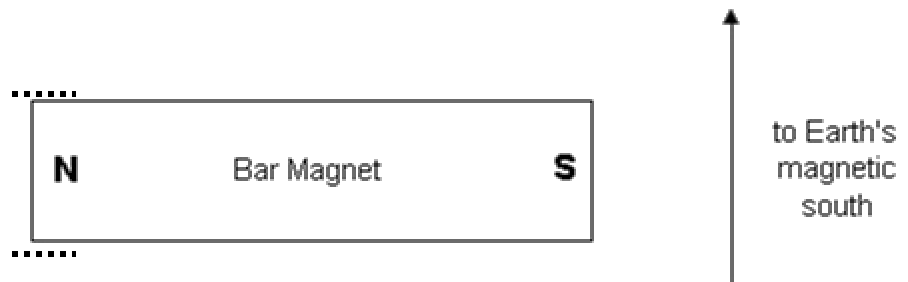
1. Which direction does the N magnetic pole of a compass needle point?
2. In which direction is geographic north (if you are standing in our classroom)?
3. Made a hypothetical model of the Earth, as a globe with a magnet in the middle. Clearly, draw a picture of this in your lab book, with a clear label of the north and south geographic poles, and the north and south poles of the magnet. Now be prepared to point to the north pole of the Earth's Iron core (which we will pretend is simply a big bar magnet).

**Part A:** Locating magnetic field lines using a compass:

Pay particular attention to the instructions (especially bold sections)!

1. Place a bar magnet at the **center** of a large sheet of air table paper on top of a large square of Lucite on top of a large box high off the floor and far from a wall (both of which could contain current-carrying wires). Orient the magnet so that its long axis is exactly perpendicular to the earth's magnetic field direction.
2. **Label** the directions to earth's geographic North and magnetic South (i.e. the "North Magnetic Pole", which is the South pole of the magnet inside the Earth) on the paper. **Position the magnet so that when you are facing toward the Earth's magnetic south (i.e. which is pretty much North) the S pole of the bar magnet is on your right.** (see picture below)
3. **Trace** the magnet shape onto the paper and **label** the bar magnet's N and S poles. Do **NOT** move the magnet or the box that it is on until the end of the experiment.
4. Starting near each corner of the NORTH end of the magnet, place 5 tick marks spaced 4 millimeters apart down the long axis of the bar magnet. (See figure below.)

one partner starts on this side



other partner starts on this side

5. Now each partner takes one of the **very small** compasses (diameter = 1 cm) and places it such that one of the tick marks lies on the circumference of the compass and such that the S end of the needle points directly to the tick mark. With a pen, make another tick mark on the opposite side of the compass, i.e., at the place to which the N end of the compass needle points.
6. Now move the compass so that the S end of the needle points at the new tick mark you just made, and again make a new tick mark on the opposite side of the compass, at the place to which the N end of the compass needle points. Keep repeating this process until the trail of tick marks reaches the edge of the paper or returns to the south end of the magnet.
7. Connect the tick marks with a smooth curve to produce a magnetic field line.
8. Repeat steps 5 - 7 for each of the remaining tick marks at the N end of your side of the magnet.

### Part B: Interpreting your magnetic field plot

1. In some unused corner of your spark paper, make a large drawing of what you would expect the magnetic field of a bar magnet to look like. Label the poles and place arrows on the field lines. Again, use your text as a reference as needed.
2. Compare your diagram from the last step with the field lines you plotted using the compass. You should notice a distinct asymmetry in your actual field lines. How can you account for this? **CALL TEACHER OVER TO CHECK AT THIS POINT**

Here's a way to see if the asymmetry in your field plot makes sense. Construct the perpendicular bisector of the rectangle that represents your bar magnet. Mark points where this line intersects your field lines on either side of the magnet. (Partners should work on opposite sides of the paper simultaneously.) Now you know, from symmetry, that the magnetic field from the bar magnet is in the East-West direction at every point on the perpendicular bisector of the bar magnet, while the magnetic field of the Earth is in the North-South direction, so they are perpendicular. Thus, if we know the direction of the net magnetic field, then we can find the ratio of the strength of the bar magnet to the strength of the Earth's field.

At the points where your field lines cross the bisector, do the following:

- a. Draw a tangent line to your plotted field (which is the net field direction), at each place the field crosses the perpendicular bisector.
  - b. Draw a vector arrow a few centimeters long to represent the Earth's magnetic field starting somewhere on the tangent line. This needs to be exactly the same length for each field line, because the Earth's magnetic field is the same regardless of how far or near you are from the magnet. Label this vector  $\vec{B}_e$  (the symbol on top of the B is suppose to be an arrow).
  - c. Knowing that  $\vec{B}_{net} = \vec{B}_e + \vec{B}_{bar}$ , (this is a vector equation!), use the parallelogram or tip-to-tail methods of vector addition to construct the vectors  $\vec{B}_{bar}$  and  $\vec{B}_{net}$  representing the magnetic field of the bar magnet and the net magnetic field respectively. (Hint: Draw  $\vec{B}_{net}$  on top of the tangent line after drawing  $\vec{B}_{bar}$  perpendicular to  $\vec{B}_e$ )
  - d. Now by measuring the ratios of the lengths of your vector triangles, you can find the ratios of the corresponding vector magnitudes. Make a data table on your paper with the following columns: the distance from the center of the bar magnet to the points of intersection, the strength of the bar magnet's magnetic field, and the net magnetic field strength (express all magnetic field strengths in units of the Earth's magnetic field). Measure and record these data for each intersection point on both sides of the bar magnet.
  - e. Plot the strength of the bar magnet's field (in units of the Earth's field) as a function of the distance from the center of the bar magnet (plot data for both sides of the magnet on the same graph). Fit a power law to these data to see how steeply the field falls off with distance. Does the magnetic field drop off as  $1/d$ ,  $1/d^2$ ,  $1/d^3$  or steeper?
3. Write a conclusion in one corner of your paper.

### Part C: Locating magnetic field lines using iron

\*\*\*\*\* **CAUTIONS** \*\*\*\*\*

1. Since the iron grains are likely to stick to your fingers (or any other body parts), try to avoid touching them unnecessarily. Nothing bad will happen if you do. They can easily be washed off when the lab is over. If you do get grains on your fingers, avoid sticking your fingers in your mouth. Eating iron grains is not an appropriate remedy for iron-poor blood.
2. Mapping magnetic field lines with a compass is somewhat time consuming, as you have just found out. A quicker method of mapping the field lines involves the use of iron grains which will orient themselves tangent to the magnetic field lines. For at least 5 different shaped magnets, place the Lucite square over the magnet and then sprinkle (NOT dump) some iron grains or chips onto the Lucite square. Draw the field-line patterns in your lab book; diagrams should be one-half page minimum.

Start with a clean (or as clean as possible) Lucite square for each different magnetic source. After completing the study of each magnet, dump the iron grains carefully onto a piece of paper, which can then be used to funnel the grains back into their cylindrical container.

3. Don't put iron grains directly onto (or nearby) a magnet. If you do, you'll have to stay after lab in order to clean the iron grains off the magnet; this is neither easy nor fun.
4. The actual magnetic fields are three-dimensional. The iron grain distribution on the squares only gives a two-dimensional slice of the actual fields. What can you do to get more than one two-dimensional slice?
  - Beware (especially with the circular magnet) of iron grains oriented perpendicular to the square; for drawing purposes: the latter can be represented by  $\otimes$ .
  - You should again include the direction to the terrestrial magnetic poles.
  - Plot what you see, not what you think you should see! Some magnets may have more than two poles.
5. You may use a compass to identify the locations of the poles if they are not obvious from the iron-grain pattern.
6. Estimate the relative strength of the various magnets. How do you do this?
7. Write a conclusion to the lab.