

## Magnetic Field Mapping

### Equipment

1	Plotting Compasses (Set of 20)	EM-8680
1	Bar Magnet Alnico (Set of 2)	EM-8620
Required but not included:		
	Paper & Pencil	
1	PASCO Capstone	

### Introduction

The purpose of this experiment is to help visualize the magnetic field by using small compasses to trace magnetic field lines for a dipole, a repulsive dipole, and a quadrupole field.

### Theory

Magnetic field lines are used to help visualize the magnetic field. There are some rules for drawing these lines.

1. The lines begin on a north pole and terminate on a south pole. This is actually only true for the field external to the magnet. Inside the magnet, the lines complete full loops and point from south to north. See Figure 1.
2. The magnetic field strength is directly proportional to the density of the field lines. This is really only true in three dimensions, but in 2-D drawings it is still true that the field is stronger where the lines are closer together.
3. The magnetic field strength ( $B$ ) is tangent to the field line at any point. Note that  $B$  is a vector.
4. The field should have the same symmetry as the magnet configuration that produced it.
5. The lines (of the total field) cannot cross (although since the compasses used to trace the lines are not infinitely small, places where the field is sharply curved can be hard to follow and lines may seem to cross.)
6. The lines cannot stop or start in space. There is one exception here. On a symmetry axis there may be a place where the field is zero. Most lines must avoid such a place, but a line on the symmetry axis must stay on the symmetry axis. On either side of the zero, the field must either point toward the zero or away from it. Thus it appears as if two lines have either started or stopped at the zero. However, there are at most only a few symmetry axes, but an infinite number of field lines (we don't draw them all). This means the fraction of badly behaved lines is (small #)/infinity = 0, so we may ignore the poorly behaved lines. Trouble is that people tend to pick the symmetry axes and see the poorly behaved lines.

A compass needle (small magnet) will align with the (average) B field at the region where the needle is as shown in Figure 1. Thus, we can use a small compass to trace the lines. Why wouldn't a larger compass work as well?

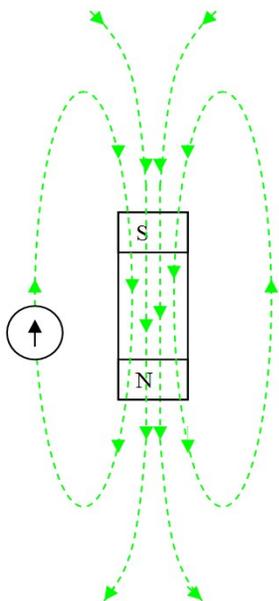


Figure 1: Dipole Field with Compass

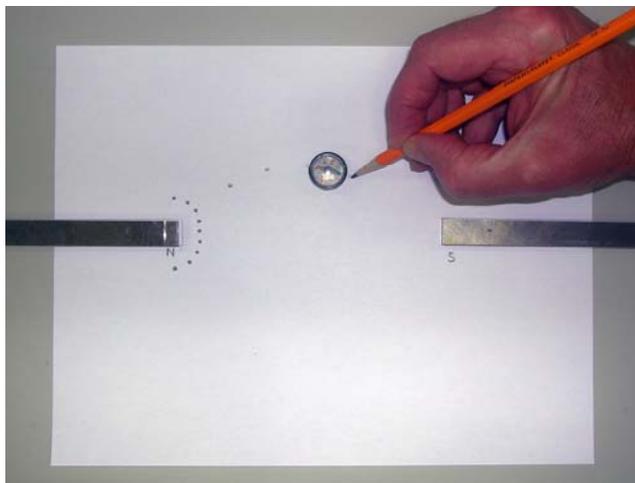


Figure 2: Attractive Dipole Setup

## Setup and Procedure

*Note 1: the PASCO EM-8620 Alnico magnet has a groove near the North end.*

*Note 2: if the laboratory tables have metal parts, they can become magnetized and add to the total magnetic fields you are mapping. You can check you table top with a compass to see if it is affected in the region where you intend to do your field plotting. If it is, find a spot that isn't.*

## Attractive Dipole

1. Position the magnets so they are about halfway onto a piece of  $8\frac{1}{2}$  x 11 inch paper as shown in Figure 2. The north pole of one magnet should face the south pole of the other. Draw a line around each magnet and label the poles. Near the north end, make a semi-circle of nine dots with one dot on the symmetry axis and four above the axis and four below as shown.
2. Position the compass so the south end of the compass points to one of the dots in the semi-circle (in Figure 2, I started at the third dot from the top). Using a wooden pencil (why?) make a dot on the paper where the north end of the compass needle points. Then move the compass so the south end points to the dot you just made and mark a new mark where the north end points. Continue until you go off the paper or reach the south pole of the other magnet. Fit a smooth curve to the dots. Don't forget that the field is a vector!

3. Now do the other eight points. Note: This should not require a lot of time. This is a quick and qualitative exercise. We are not working to three significant figures.

### Repulsive Dipole

1. Set up as before with the two north ends facing. Draw a semi-circle of nine dots around each North pole. See Figure 3.
2. Trace all 18 lines.

### Quadrapole

1. Tape two pieces of paper together. Draw an arrow on the paper with the north direction indicated as shown in Figure 4. With the magnets far away, use your compass to align the paper so the arrow points at magnetic north. Tape the paper down so it can't shift position.
2. Put the magnet on the paper at about a 45 degree angle as shown. Mark the position of the magnet and indicate which pole is north.
3. Put a semi-circle of nine dots around each pole. In addition, put two dots along the body of the magnet and above the magnet near the north end (see Figure 4) and a matching two dots below it (the compass South pole is pointing to one of them).
4. Trace all 22 lines.



Figure 3: Repulsive Dipole

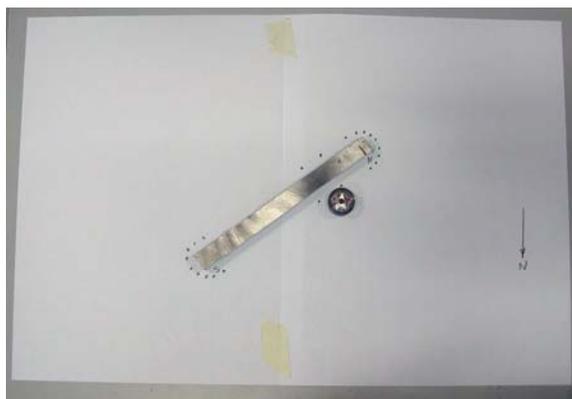


Figure 4: Quadrapole

### Analysis

Discuss each of the three patterns briefly. Consider the six points discussed in the Theory section. Where is the field relatively strong? Are there any symmetries? Are there any zeroes? Do the lines cross? Do any lines start or stop in space?

