

Lab 05 - Magnets, Magnetic Fields, and Electric Fields

NAME: _____

Time spent on Lab 05 = approximately 2-3 hours, does not need to be done at one sitting

Materials needed = Access to computer and high speed internet, Java installed on the computer, TWO of any sort of magnet you would find at home (i.e. fridge magnets), one metal paperclip, one aluminum beverage can, one compass

Learning Objectives:

- Experiment with magnets and magnetic materials
- Visualize and quantify magnetic fields

In this week's lab, we will begin exploring the properties of magnets, magnetic fields, and how these affect electric charges. Let's warm up with some activities you can do around the house.

At-home activities:

First begin by grabbing two magnets that you might find lying around home. If they are fridge magnets, or similar, then place the two faces towards each other about 10 cm apart, and slowly bring them close together.

1. Do you feel any force, push or pull, interacting between the magnets? Describe what you notice. Be sure to comment on the distance between magnets.

There is a force that pulls the magnets together and it increases as the magnets are brought closer until they snap together.

2. Now, flip ONE magnet to the other face, and repeat the experiment, starting about 10cm away from each other and then slowly bringing them together. Do you notice a push or pull? Explain and again be sure to comment on distance.

There is a force that pushes the magnets away and its strength increases with the reducing distance between the two magnets and vice versa.

As you may have heard, all magnets are dipoles, meaning they have two opposite ends which create opposite physical characteristics. We refer to them as North and South ends of a magnet. One could call them positive and negative, like electrical charges and they would have the same effect in nature, so north and south are really just arbitrarily chosen designations. A standard picture one might have of a magnet is depicted below.



Figure #1

Notice the two ends of this horseshoe are labelled N and S for north and south. One could say they are the same magnitude, but opposite directions, if you want to think of them in terms of vectors. Similar to electric charges, **in magnetism, opposites attract, and likes repel**. So when you brought two poles of the magnet together that were the same, they repelled each other, and when you brought two poles of the magnet together that were different, they attracted one another.

3. Now take one of the magnets and bring it close to a metal paperclip. What do you notice? Repeat this procedure, only be sure to hold the paperclip in your hand. Comment on the effect of distance.

The paperclip is pulled towards the magnet. The force gets stronger when the magnet is brought closer and gets weaker as the distance between them is increased.

4. Assume you just used the “north” end of the magnet in #3 (though we don’t know this for certain). Repeat #3 with the “south”, or opposite, end of the magnet and write down your results below.

The paperclip is also pulled towards the magnet as in 3 above.

You might begin to ask yourself, why do opposite ends behave the same way with a metal paperclip!? That seems strange. With electrical charges, oppositely charged particles behaved differently, didn’t they?!

In the case of magnets, they have opposite characteristics, WITH RESPECT TO EACH OTHER, but in some cases, they behave similarly. In the case of attracting a paperclip, paperclips have some iron in them, and so they have “magnetic properties”. Entire research fields are dedicated to the study of magnetic properties, but we will simply state matter is made up of tiny magnets. When a material has magnetic properties, and it is close to a strong

magnet, the tiny magnets align just like the magnet near them! An image of this is depicted below.

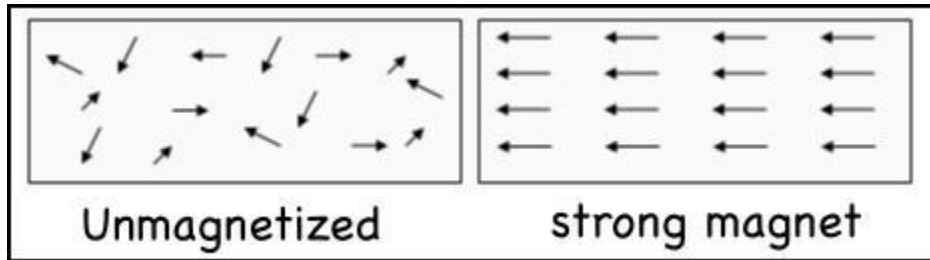


Figure #2

Imagine this is a block of iron and arrow tips are the direction of North on the tiny magnets that the iron block is made of. In the left image, the block is isolated, not near any magnets. So the tiny magnets, [magnetic domains](#), which it is created from, are randomly aligned. The right picture shows the iron near a strong magnet, which will cause the magnetic domains to have a similar orientation as the big magnet which is nearby.

5. Notice we are careful to state “nearby” in the explanation above. Why is that? Think back to your answers in #1-#4.

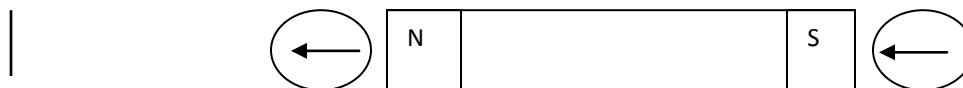
Iron has strong magnetic properties and its magnetic domains only align when it is brought near the magnet where the magnetic pull is strong unlike when it is placed far from it.

6. Now repeat the procedure for #3 and #4 with the aluminum beverage can. Write a summary of your results below.

The can was not pulled towards the magnet on both sides.

Many people often associate ALL metals as being heavily attracted to magnets, but that is simply NOT the case. Many metal materials have no iron and therefore when their magnetic domains align, similar to iron, they feel a very weak attraction to the magnet. Aluminum is one such metal.

7. To illustrate magnetic domains better, bring a compass close to one side of the magnet, make note of which end of the compass is pointing to that side, and then bring the compass to the other side of the magnet, and make note of which side of the compass is pointing towards that side. Illustrate your results in a sketch or photo below.



The compass needle should always point the magnetic north pole of the earth, but when it is near the magnet, the needle “re-aligns” in the same orientation as the magnet, where the north

pole of the needle touches the south pole of the magnet, and vice-versa for the north pole of the needle.

Now, you might be asking yourself, what is it about the magnet that causes the magnetic domains in metals, and compass needles, to align in the same way? The answer to that question is the magnetic field! To study this invisible field, we will need to make use of computer simulations!

Virtual Lab:

First proceed to:

<https://phet.colorado.edu/en/simulation/legacy/magnet-and-compass>

And download the most recent version of the Phet “Magnet & Compass” lab.

Once the lab is downloaded and open, then you should see a screen similar to this:

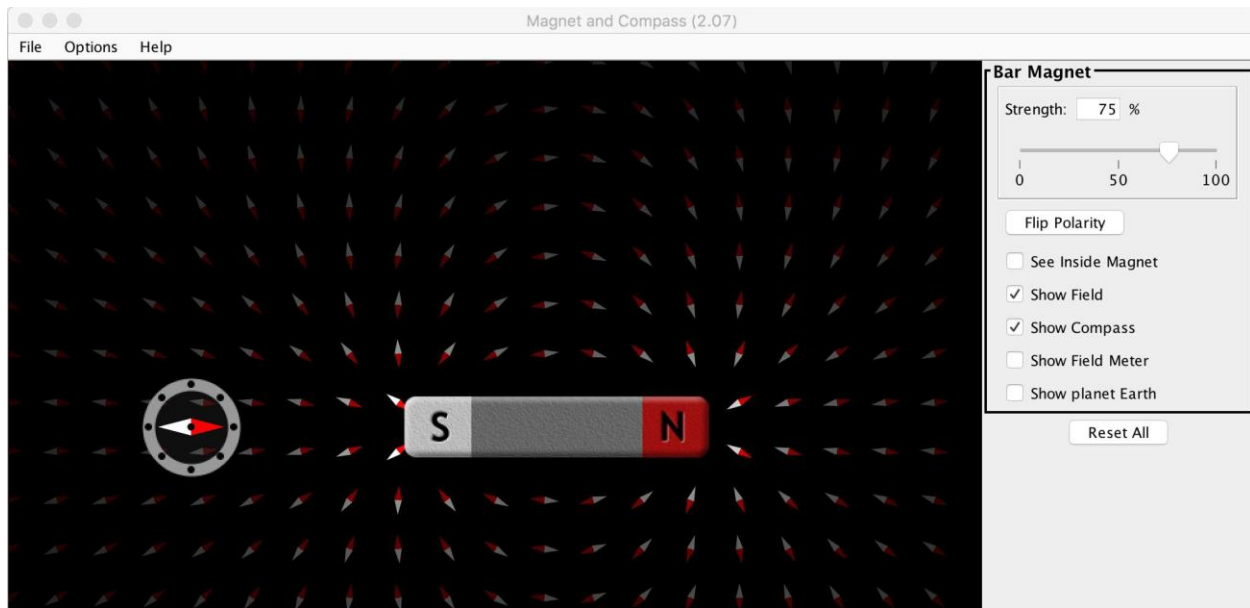


Figure #3

The item on the left is a compass which is near a bar magnet, or something similar to a fridge magnet, but in the shape of a bar. Easy enough! You can see that the right side of the bar is labeled N for North and the left, S for South. So far, so good! So what are those little red/white indicators all around the bar magnet? That is what we need to find out!

8. Move the compass around to four different positions around the bar magnet and comment on how the direction the compass points changes at each position.

At the South end of the magnet, the compass needle pointed towards the magnet while at the north, it pointed away from it. At the West and East positions, the compass needles both pointed in the South direction.

One way to think of the little red/white marks around the magnet is as if they are little compasses which point in certain, well-defined directions.

Now click on “See Inside Magnet”. You will hopefully see the same little compasses inside the magnet, following in the same direction as the compasses just outside the bar magnet. Similar to what we saw with magnetic domains. As it turns out, many magnets are just elements, which have had their magnetic domains “permanently” aligned. This alignment inside the magnet, creates a “generated” alignment of any nearby magnetic domain nearby the magnet. Similar to if you have mass, then the mass generates a force of gravity. If you have an aligned magnetic domain in a magnet, then this magnet generates A [Magnetic Field](#)!

To make a long story short, the little compasses around the magnet align themselves in the direction of the Magnetic Field, which we denote as the vector **B**. Below is an image which shows several mini-compasses overlaid on the magnetic field generated by the magnet.

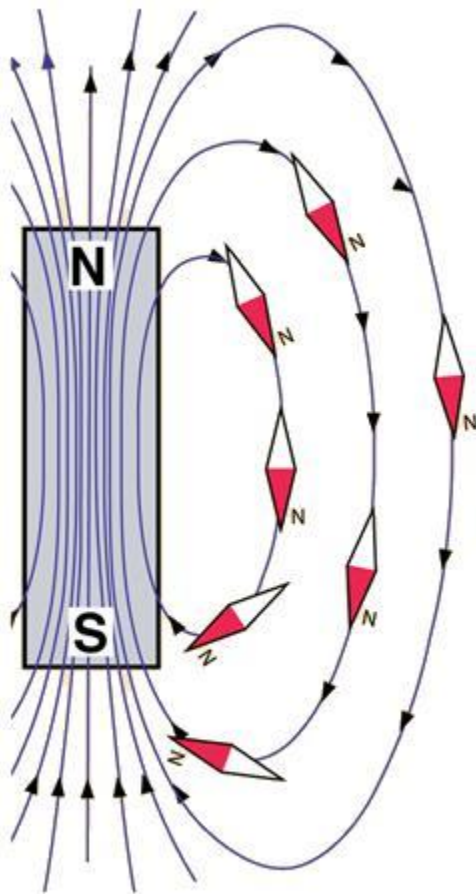
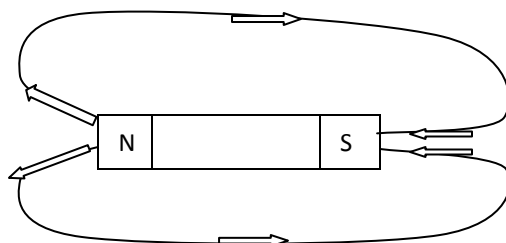


Figure #4

9. Think back to when you ran a compass around your magnet at home. Looking at your compass and magnet, make a quick sketch of the magnetic field of your magnet below.



Let's talk a LITTLE theory with respect to the magnetic field of a bar magnet. The magnetic field of a bar magnet along the axis of the magnet SHOULD take on the form of $B_{\text{axis}} = \frac{\mu_0 m}{2\pi d^3}$, where B_{axis} is the magnetic field along the axis of the magnet, d is the distance along the axis of the magnet, μ_0 is the physical constant $3.14 \times 10^{-11} \text{ T}\cdot\text{m/A}$, m is a measure of the magnet strength, like Q for electrostatics, and μ_0 is the permeability of free space, another physical constant of $12.56 \times 10^{-11} \text{ T}\cdot\text{m/A}$.

10. Use the magnetic field sensor to measure 5 data points along the axis of the magnet. Notice, we do NOT know the units of distance, so simply keep them at equal intervals and label them 1, 2, 3, etc. without units. Put your data in the table below.

Magnetic Field Strength	Distance
191.32	1
217.67	2
220.65	3
217.73	4
191.32	5

11. Use a [google spreadsheet](#) to graph Magnetic Field Strength versus Distance. What shape SHOULD the data have? Comment on this below. Then fit a [linear trendline](#) to the data along with the R^2 value and write both below. Do the values make sense? Explain.

The data should give a bell shape since the values increase and then decrease equally with a central high value. $R^2 = 0$ and this make sense because the values are close to the mean and do not differ significantly.

The nice thing about magnets, is that they behave VERY similarly to two charges spaced at a certain distance from each other. We call this behavior a “dipole” and so a magnet is a dipole with a north and south pole. A positive and negative charge next to each other are dipoles of positive and negative charges. Notice the similarity between the magnetic field in figure #4, to the electric field in the figure below.

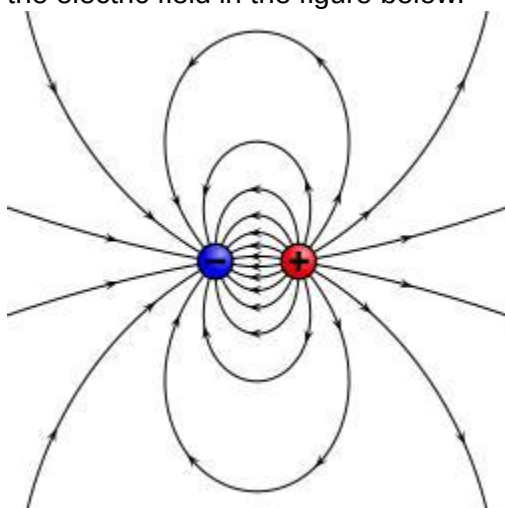


Figure #5

Both are magnetic, or electric, dipoles and so their mathematical models are quite similar.

Once you have completed all lab questions, please download this document as a PDF only! Then upload this PDF to Blackboard under the assignment “Lab 05”, for grading.