§ 1 Introduction

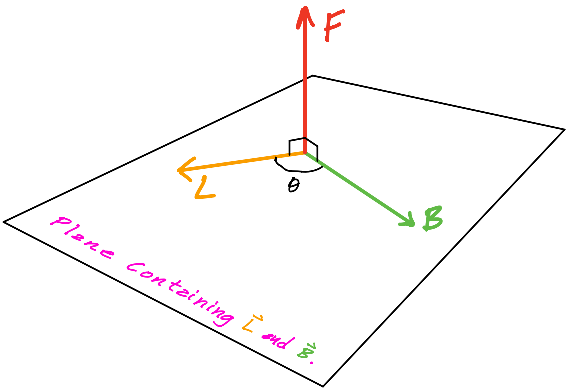
In this lab we will get to know the magnetic field a little bit. We will observe the magnetic field produced by a permanent magnet, and then measure the force this field produces on a current.

§ 2 Background

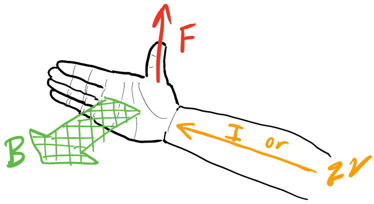
The force $\vec{F}$ on a length L of wire carrying a current I in a field $\vec{B}$ is

$$\vec{F}_B = I\vec{L} \times \vec{B}$$

where the vector $\vec{L}$ points in the direction of the current. This equation represents mathematically both the direction and magnitude of the magnetic force. The direction of the field is perpendicular to the plane created by the two vectors $\vec{B}$ and $\vec{L}$.



Because there are two directions perpendicular to a plane (up and down) we need a way of choosing which of the two is the direction of the force. This rule is usually stated in terms of a "right hand rule", which is depicted in the diagram below.



The magnitude of the force is

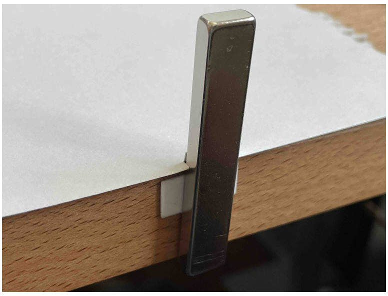
$$F_B = ILB \sin\theta$$

where θ is the angle between $\vec{L}$ and $\vec{B}$.

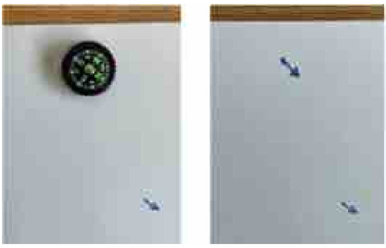
§ 3 Mapping the field

The goal of this section is that you will be able to see (in your minds eye) the invisible magnetic field lines around your magnet. You will need to be able to see these in order to understand the rest of the lab.

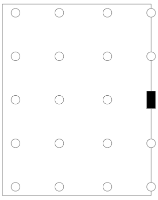
Find the three small compasses, and the magnet in your kit. Sometimes the orientation of a compass can get flipped. Put all three compasses near each other and about 20 cm from the magnet. If one is opposite the others discard it. Otherwise pick the compass that seems to point closest to the average direction of the three. Put the other two aside.



- Next use a small piece of the double sided tape to stick the magnet to the edge of a table as shown to the right.
- Cut a piece of paper in half. Then take one half and fold that that in half. Cut two small slits in the folded side so that you can put the paper around the magnet as shown.



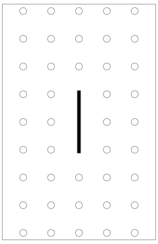
Now use a compass to find the direction of the magnetic field. Next remove the compass and draw a small arrow on the paper where the compass was in the direction the compass was pointing.



Repeat this field mapping at the approximate locations indicated in the diagram to the right. Once this is done. Unstick the magnet and rotate the magnet around the vertical axis 180° and stick the opposite face to the table. Also flip the paper over. Map the field on this side of the paper. When you are done unfold the paper and lock at the full field map.

▷ Question 1
Is the field the same on both sides of the magnet?

▷ Question 2
If you were to lay the magnet on its face on the table, what would be the direction of the field at the surface of the table?

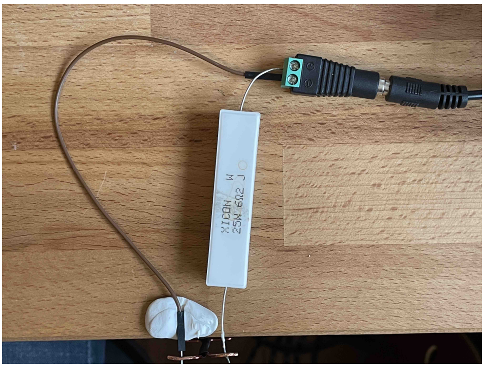


Next take the other half sheet of paper and place the magnet on its narrow edge in the center as indicated. Map the field at the approximate locations shown in the diagram to the right. Mark the face of the magnet where the field is coming out of the magnet with ⊙ symbols. Mark the face of the magnet where the field is going into the magnet with ⊗ symbols. You can put the mark on a small piece of paper and then tape the paper to the face of the magnet.

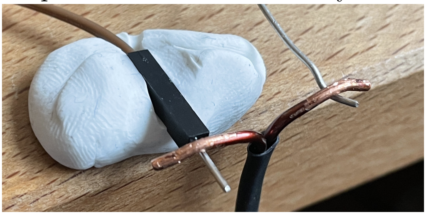
§ 4 Direction of Magnetic Force

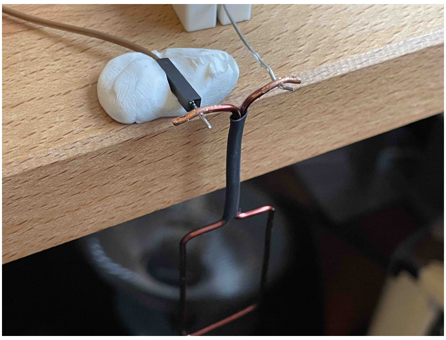
Now we will set up a current and see what happens when we put it in a magnetic field. Using the parts in the kit set up the circuit below. **WARNING**: Do not plug the power supply in until after everything is set up. The large ceramic block is a resistor and will get hot enough to **burn you**, and the longer you leave it plugged in the hotter it will get. If you have a plastic desktop it will melt the plastic. So make sure that the resistor is on top of something that can take the heat and don't plug in the power except while making the measurements.

The setup is a bit finicky so be patient. The wire of the hanging loop has an insulating coating on it. **You will need to scape off this coating at the ends.** A razor blade of knife will work fine. You want to get down to clean copper.



The resistor lead can be shaped a bit with the pliers to make a cradle for the ends of the loop so that the loop does not fall off so easily.





▷ QUESTION 3
Will the current in the bottom edge of the loop go to the right or to the left?

▷ QUESTION 4
How would you hold the magnet so that there is a field going upward in the region of the bottom edge of the loop.

▷ QUESTION 5
How would you hold the magnet so that there is a field going downwards in the region of the bottom edge of the loop.

Now plug in the power supply and bring the magnet near the bottom edge of the loop. Notice the direction of the force on the wire for the case of the magnetic field upward and downward.

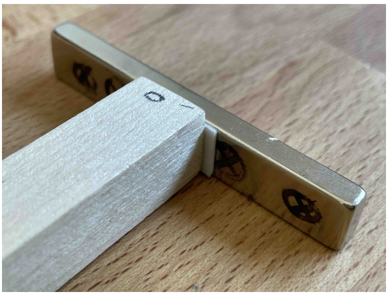
▷ QUESTION 6
Is the force perpendicular to both $\vec{B}$ and $\vec{L}$?

▷ QUESTION 7
Does the direction of the force follow the right hand rule?

§ 5 Magnitude of the force

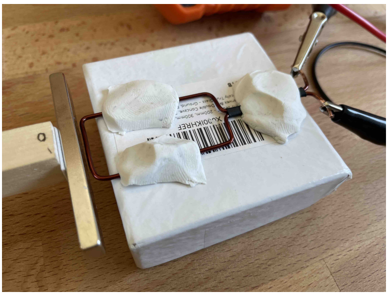
Now we will measure the magnetic force on the loop. Take the long stick from last semester and mark it at 30 cm from one end and 60 cm from the same end.

Now use the remaining double sided tape to attach the magnet to the end of the stick as shown to the right. Attach the magnet to the end of the stick from which you measured 30 and 60cm.

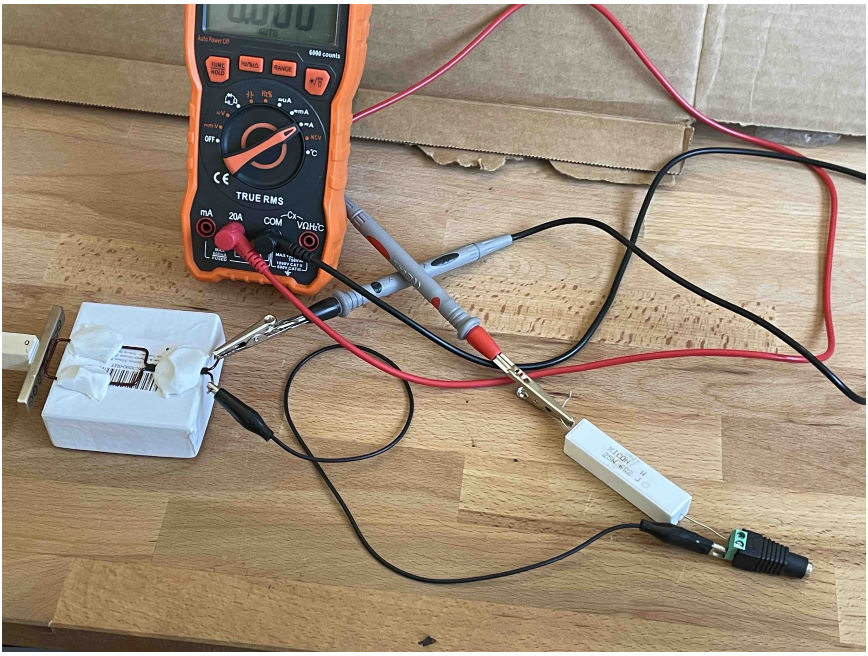


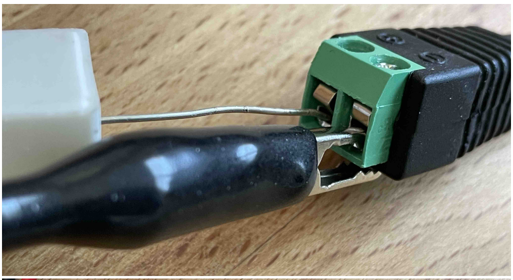
Next put the stick on top of the scale as shown below.

Next use the clay to stick the loop to the top of the box of lenses as shown. This should place the end of the loop at the center of the magnet. If not adjust the height up or down.



Now connect up the circuit as shown below. There are details of the connections in the subsequent photos. Pay particular attention to the DMM connection. You have not used this setting or connection before.





▷ QUESTION 8
Draw the circuit digram for the circuit you just built.

▷ QUESTION 9
What direction is will the current be going through the end of the loop when you plug in the power supply?

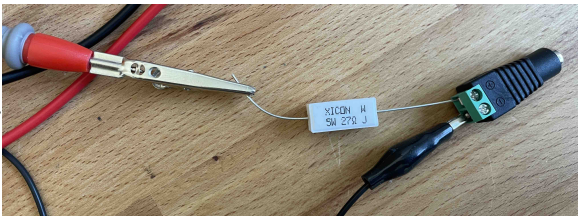
▷ QUESTION 10
What direction is the magnetic field at the location of the end of the loop?

▷ QUESTION 11
What is the direction of the force on the loop?

You are now set up to make a measurement of the force. Tare the scale to remove the weight of the stick and magnet. Then plug in the power supply and turn on the meter to measure current. Record the current and reading on the scale. **Disconnect the power supply.**

Now trade out the 6Ω resistor for the 12Ω resistor as shown to the right and repeat the measurement. **Disconnect the power supply.**

Now trade out the 12Ω resistor for the 27Ω resistor as shown to the right and repeat the measurement. **Disconnect the power supply.**



▷ QUESTION 12
Does the direction of the force (± sign of the measured weight) agree with your prediction?

§ 6 Analysis

Now compute the force F_B for each of the three current level, from the measured reading on the scale, and then graph this force versus the current. Also include the point $F_B = 0$ for $I = 0$. The force applied by the scale is

$$F_s = m_s g = m_s \left(0.0098 \frac{\text{Newton}}{\text{gram}} \right)$$

where m_s is the mass reading on the scale in grams. Because of the position of the scale under the midpoint of the stick the force on the scale is twice the magnetic force applied to the wire by the magnet, $F_s = 2F_B$, thus

$$F_B = \tfrac{1}{2} F_s = \tfrac{1}{2} m_s \left(0.0098 \frac{\text{Newton}}{\text{gram}} \right)$$

Now fit a straight line though the points and compute the slope of the line.

▷ QUESTION 13
Does a straight line fit the observed data?

▷ QUESTION 14
Can you use the slope to determine the magnetic field strength? Recall that the theoretical prediction for the magnitude of the force is $F_B = ILB\sin\theta$.