LABORATORY 8
MAGNETISM II: FORCE ON A CURRENT-CARRYING WIRE

Objectives

- to be able to determine the magnitude and direction of the force on a current-carrying wire in a magnetic field
- to be able to apply Newton's Laws in magnetostatics
- to be able to experimentally determine the relationship between the force on a current-carrying wire in a magnetic field and the current through the wire
- to be able to experimentally determine the relationship between the force on a current-carrying wire in a magnetic field and the length of the wire
- to be able to experimentally determine the relationship between the force on a current-carrying wire in a magnetic field and the angle between the wire and the magnetic field

Overview: In this lab, we will explore the magnitude and direction of the force on a current-carrying wire and its dependence on the magnitude of the current, the length of the wire and the angle between the current-carrying wire and the magnetic field.

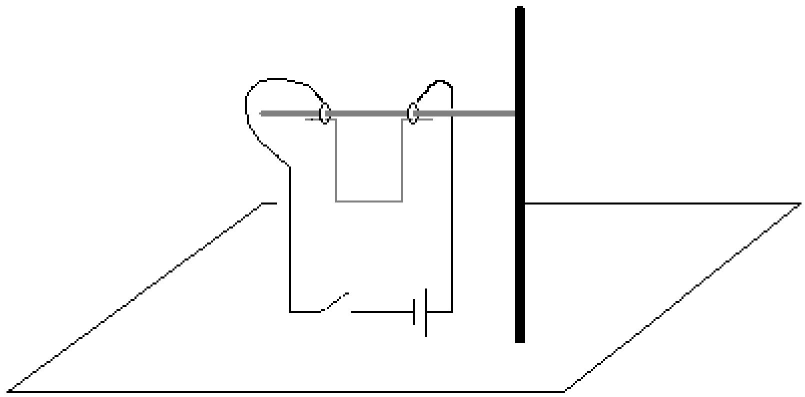
Equipment:

1 current-carrying wire set-up consisting of:
(1 rod stand, 1 wood rod,
1 switch, 1 battery, 1 battery holder
6 wires with alligator clips,
2 paper clips,
1 wire with both ends stripped)
1 cow magnet

Exploration 1: Direction of force on a current carrying wire I

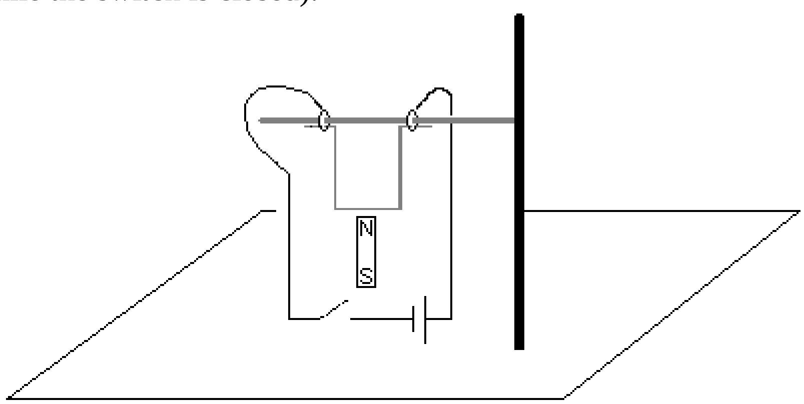
Exploraton 1.1 Take the pre-test for this lab.

Exploration 1.2 Consider the setup shown below, which is set up at your lab table. The wire suspended from the paper clips is free to swing. The current flows from the battery through the alligator clip wires, through the swinging wire and back to the battery.



Determine the direction positive current will flow through the swinging wire when the switch is closed. (Do not close the switch yet.) Draw the direction of the current on the diagram.

a. This is a prediction. Do not carry it out yet. Suppose you were to close the switch and bring the north pole of a cow magnet up under the wire, as in the diagram below (while the switch is closed).



(i) What is the approximate direction of the net magnetic field of the magnet near the wire? Explain your reasoning.

(ii) Which direction, if any, would the wire move? Record your prediction for the direction of motion of the wire. Explain your reasoning for your choice of direction or explain why it wouldn't move.

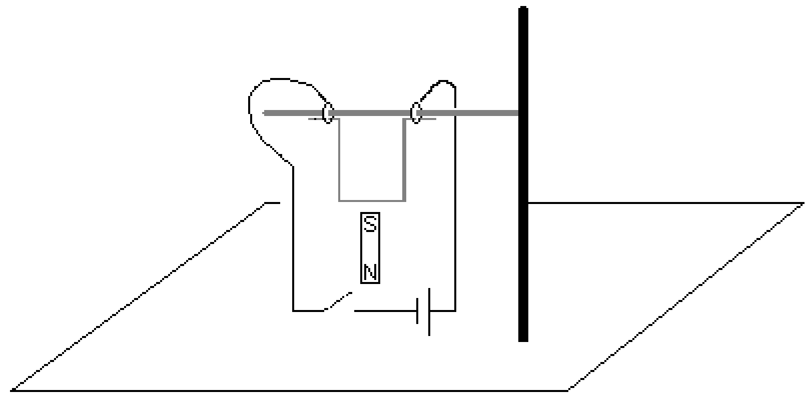
b. Carry out the experiment in part **a.** With the switch closed, bring the magnet up under the wire. Observe the direction of motion of the wire. Do not hold the switch down for long periods of time, or you will run down the battery quite quickly. The motion may be small, but you will be able to see it. Record the direction of the motion. Draw the direction of the field, the direction of the current and the direction of the force on the wire in the picture above.

c. Now predict the motion of the swinging wire, if you turn the magnet around, so that the south pole is up, keeping the direction of the current through the wire the same as in part **b.** Answer the following questions:

(i) What is the approximate direction of the net magnetic field of the magnet near the wire? Explain your reasoning.

(ii) Which direction, if any, would the wire move? Record your prediction for the direction of motion of the wire. Explain your reasoning for your choice of direction or explain why it wouldn't move.

d. Carry out the experiment in part **c.** With the switch closed, bring the magnet up under the wire with the south pole up. Observe the direction of motion of the wire. Do not hold the switch down for long periods of time, or you will run down the battery quite quickly. The motion may be small, but you will be able to see it. Record the direction of the motion. Draw the direction of the field, the direction of the current and the direction of the force on the wire in the picture below.



e. Turn the battery around, so that positive current flows the other direction through the wire. Repeat parts **a. – d.** for the current flowing in the other direction. Record your results in the table below.

Direction of magnetic field	Direction of current	Prediction for the direction of the force on the wire	Observation of the direction of the force on the wire

Discuss your results with your TA.

Equipment:

1 current-carrying wire set-up
1 power supply
1 ammeter

Exploration 2: Direction of force on a current-carrying wire II

At your table, is the main unit you will be using today, mounted on lab stand. It is shown in the picture below. Place one of the current loops into the end of the main unit, with the foil extending down into the magnet assembly and position the lab stand with the Current Loop down between the poles of the magnet. The Current Loop should not be touching the magnet.

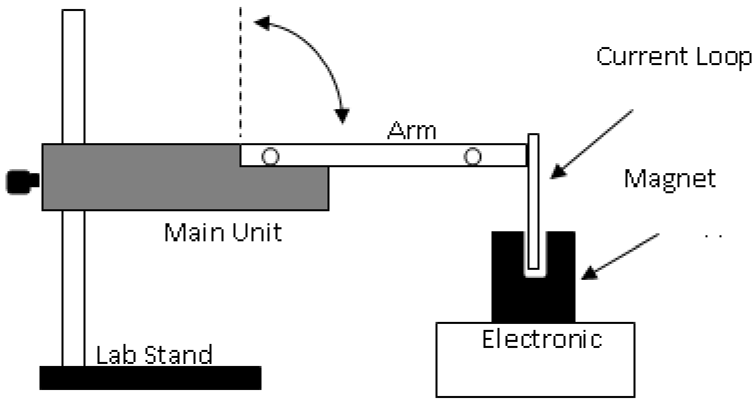
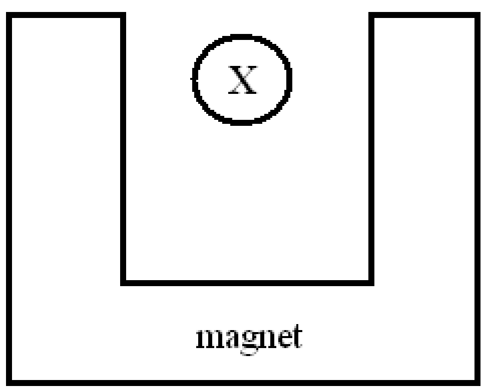


FIGURE 1.

You will be attaching a power supply to the current loop, so that you can send current through the loop.

a. This is a thought question. Do not set it up yet. If, in the picture above, the magnetic field between the poles of the magnet is to the left, and current is sent through the loop so that the current is into of the page, would there be a net force on the wire? The situation is illustrated in the picture below. Draw the direction of the force on the wire in the picture below.



b. Is there a net force on the magnet? If so, which direction is the force? If not, why not? In either case, explain why there is or is not a force and how you know the direction of the force.

Discuss your answers with your group. After you have a group discussion, the TA will have a class discussion about the questions in parts **a.** and **b.**

In Explorations 1 and 2, we have been focusing on the direction of the force on a current-carrying wire. It is obtained by using a right hand rule. Make sure you understand the right hand rule and how to use it to determine the direction of the force on a current-carrying wire when the direction of the magnetic field and the current are known.

The magnitude of the force on a current-carrying wire is given by

where I is the amount of current through the wire, *L* is the length of the wire, B is the magnitude of the magnetic field and θ is the angle between the magnetic field and the direction of the current. In the Investigations below, we will quantitatively explore the magnitude of the force on a current-carrying wire and explore its dependence on I, L and θ.

Equipment:

1 current-carrying wire set-up
1 power supply
1 ammeter

Investigation 1: Relationship between force and current in a current-carrying wire

In this section we will explore the relationship between the force on a current-carrying wire and the current through the wire.

Investigation 1.1

Set up the main unit as in Exploration 2: Mount the main unit on the lab stand, place one of the current loops into the end of the main unit, with the foil extending down into the magnet assembly and position the lab stand with the Current Loop down between the poles of the magnet. The Current Loop should not be touching the magnet.

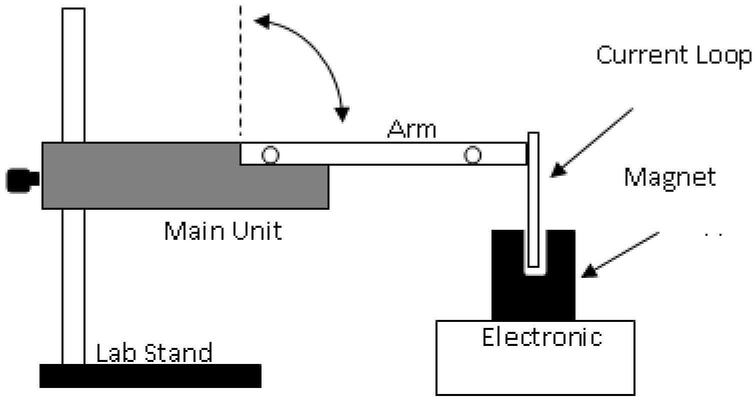


FIGURE 1.

a. Predict the dependence of the force on the current. If you were to plot the force vs. current on linear graph paper, what would you predict for the shape of the curve? What would be the slope of the curve? Could you determine the magnitude of the magnetic field from the data? How?

b. Place the Magnet Assembly on the Electronic Balance. Zero the reading on the balance, so the weight of the magnet is subtracted from the reading and the force of the current-carrying wire on the magnet is the only force measured by the balance. There will either be a zero function on the balance or a function labeled "tare" to zero the reading.

Make sure the lab stand is positioned so that the Current Loop is between the poles of the magnet and not be touching the magnet.

With the power supply off, connect the power supply and ammeter as shown in Fig. 2, so that the force on the magnet is downwards and the ammeter will read a positive current when the current is turned on. Turn the *Voltage* knob on the power supply completely clockwise. The *Current* knob should be completely counterclockwise. Turn on the power supply. **Slowly** turn the Current knob clockwise to check if you have correctly connected the power supply and ammeter so that the ammeter reads positive current. If not, turn the current down and the power supply off and check your connections.

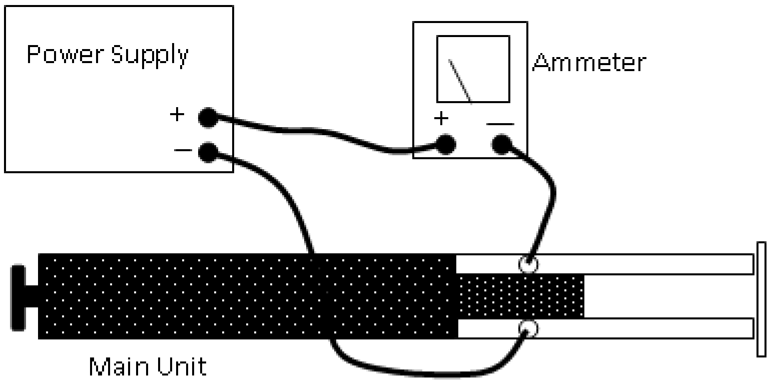


FIGURE 2. Connections for the Main Unit, Ammeter and Power Supply (Top View)

Show your connections to the TA before proceeding.

Once you are sure your setup is correct, start with a current of 0.5A and take current readings from 0.5A to 3.0A in increments of 0.5A, recording the current and the force of the wire on the magnet in the table below.

Current	Force

c. On graph paper or in Excel, plot force vs. current. How does the force depend on current? Do a best fit to your data.

d. From your graph, determine the magnitude of the magnetic field. Discuss your process in words and show your calculation clearly.

Equipment:

1 current-carrying wire set-up
1 power supply
1 ammeter

Investigation 2: Relationship between force and length of a current-carrying wire

In this section we will explore the relationship between the force on a current-carrying wire and the length of the wire.

Investigation 2.1

a. Predict the dependence of the force on the length of the wire. If you were to plot the force vs. current on linear graph paper, what would you predict for the shape of the curve? What would be the slope of the curve? Could you determine the magnitude of the magnetic field from the data? How?

b. Keep the current reading at maximum for this part of the experiment. Record the force and the length of the loop you used in the experiment you just did for the highest current reading. The lengths are given in the following table and the corresponding number is written on the loop.

Current Loop	Length
SF 40	1.2cm
SF 37	2.2cm
SF 39	3.2cm
SF 38	4.2cm
SF 41	6.4cm
SF 42	8.4cm

Swing the arm of the Main Unit up to raise the present Current Loop out of the magnetic field gap. **Carefully** remove the Current Loop from the arm of the base unit. Do not pull from the bottom of the Current Loop unit but from the sides (near the nuts) so as to avoid breaking the loops. Replace the Current Loop with a new Current Loop, with a different length of wire. Carefully lower the arm into the center of the magnet. Make sure the unit is not touching the magnet but is centered as closely to the magnet as possible.

This time, you will take readings of the force for each of the different lengths of wire at the same current reading. Record your readings in the table below.

Length of loop (m)	Force

After all measurements have been taken, turn the current knob on the power supply to zero.

c. On graph paper or in Excel, plot force vs. length of loop. How does the force depend on the length of the loop? Do a best fit to your data.

d. From your graph, determine the magnitude of the magnetic field. Discuss your process in words and show your calculation clearly.

Equipment:

1 current-carrying wire set-up
1 power supply
1 ammeter

Investigation 3: Relationship between force and angle between the current through a current-carrying wire and the magnetic field

In this section we will explore the relationship between the force on a current-carrying wire and the angle between the current and the magnetic field.

a. Predict the dependence of the force on the angle between the current and the magnetic field. If you were to plot the force vs. current on linear graph paper, what would you predict for the shape of the curve? What would be the slope of the curve? Could you determine the magnitude of the magnetic field from the data? How?

b. Replace the Current Loop with the Current Balance Accessory on the main arm so that the coil of wire is down when the arm is down, as in Fig 3 below. Set the dial on the unit to 0°. Align the Magnet Assembly so that the magnetic field is parallel with the wires of the coil. With the current turned off, zero the balance so that you are not measuring the weight of the Magnet Assembly. Turn on the power supply and set the current to **2.0 amps**. **Do not exceed 2 Amps in this part of the experiment!** Record the force of the Current Balance Accessory in the 0° position. Rotate the dial **clockwise** in 5° increments, taking new force readings at each setting. Record the force and the angle between the magnetic field and the wire for each increment in the table below. Then rotate the dial **counterclockwise** from 0° in 5° increments recording the force and the angle between the magnetic field and the wire for each reading. Do Not turn off the Electronic Balance when you have finished taking data.

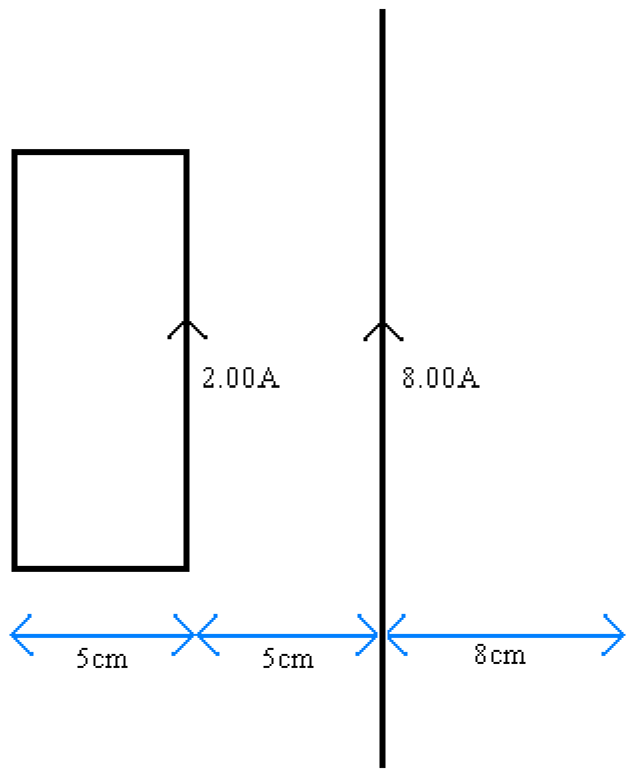
c. On graph paper or in Excel, plot force vs. the angle between the current and the magnetic field. How does the force depend on the angle between the current and the magnetic field? Is the data consistent with your prediction?

d. From your graph, determine the magnitude of the magnetic field. Discuss your process in words and show your calculations clearly.

Summary. Briefly summarize your results from Investigations 1, 2 and 3.

Laboratory Homework 8
Magnetism II: Force on a current-carrying wire

1) Consider a rectangular loop of wire placed in the same plane as a straight wire, as shown in the diagram below. A current of 2.00A runs through the rectangular loop. The dimensions of the loop are 1m x 0.5m. A current of 8.00A runs through the wire.



Does the loop experience a net force? If so, determine the magnitude and direction of the net force on the loop. If not, explain why not. Show your work and explain your reasoning.