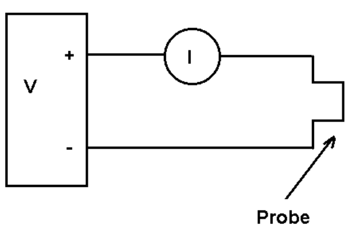
The Current Balance Pandemic Edition 2023

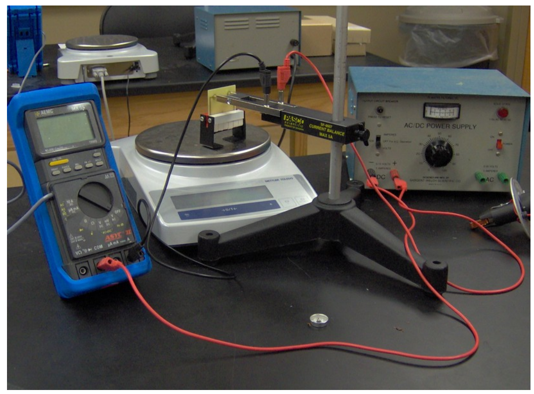
Note: only close the acquisition program with t!

From today's lab: you should verify the Lorentz force law, measure the direction of magnetic field and also know how to measure magnetic field strength.

In the first part of this lab, you are to verify certain aspects of the force of interaction between a current and a magnetic field. We have a fixed magnetic field and we will, in the first experiment, run a known current through a wire in order to determine the force on the wire. By reversing the current direction, the force will appear in the opposite direction. The easiest way to reverse your current is to change the leads on your power supply.

The circuit diagram for this experiment is quite simple as shown below.





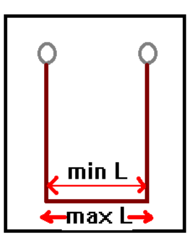
Part I

If we assume a constant magnetic field, then a current in a magnetic field will experience a force

$$F=ILB$$

where I is the current through the wire, L is the length of wire exposed to the magnetic field and B is the magnetic field. **This also assumes that the magnetic field is at right angles to the current.**

On your electronic scales, choose the force readings to be provided directly in kg (I should already have the scales set to do this). We do not have direct access to the value of magnetic field but your measurements will provide us with this measurement and, in fact, you will make a fairly good measurement of the magnetic field in Tesla.



The first part of the lab is fully computerized with regard to data acquisition. You should use the 10A DC scale of the MX55 and you additionally should choose the 10 MΩ input impedance. The procedure is fairly straight forward for the first part of the experiment. You have 6 circuits of varying lengths (notice that two have the length doubled on the back). You will need to measure the inner and outer lengths of the portion of the circuit which will be in the magnetic field and perpendicular to the magnetic field. The difference in these measurements will be a source of uncertainty in your magnetic field measurement. You'll want to record these values in the table below. If your circuit is doubled, you might want to make a special notation about this. I have provided the length measurements in your spreadsheet helper in the pandemic version.

You should vary your current from 0.5 to 5A in steps of about .75 A or so. You will need to run the program "current balance" to acquire the data.

I recommend naming the files something simple like, for example, "sf40". You will take data by pressing the space bar. however, when you increase the current, do so slowly and give the balance several seconds to settle down. Failure to do this will result in degradation of your data and results and you will need to repeat them.

Do not exceed 5A in this experiment (you might use a current of say 5.1 but don't go higher). You won't need to exactly have, for example 4.00 A ... if you have 4.5 A, that would be an acceptable data point. You'll also notice that the power supplies have some trouble to maintain a current of 5 A (stay lower please). You should align your circuit so that a positive current results in a positive force. **At least once, during today's lab I do want you to confirm that a negative current then causes a negative force and also that if you reverse the direction of the magnet, what was a positive force will become a negative force.**

Here is a check off for you: make sure you do these confirmations.

Confirmation 1: _______ Confirmation 2: ________

(write this as an observation in your report).

Hint:

Work through this with the right hand rule. Conventional current runs from red to black, find the direction of the magnetic field (red to white or whie to red) with the compass held above the magnet then use the right hand rule. Do not forget to calibrate your compass.

Be sure you read the paragraph below!

Note: Make sure you tare the scales at zero current to insure that you will see these results. You will also want to make sure the scales are leveled by rotating the legs on the bottom until the bubble on the scale is correctly centered. Hopefully this condition will already exist.

I want you to make measurements for each of the circuits provided. You will probably want to practice a few runs before you begin to take data for analysis. Make sure you feel comfortable with changing the current and waiting long enough for things to settle before commanding the computer to take the data point.

After you complete this portion of the experiment you will paste your data into the excel spreadsheet which I have prepared to help with your lab today. Paste your data into the

OpenOffice spreadsheet "current balance" using paste special : with the option detect special numbers. Be sure to look through your data (and plots) for obviously bad data points and if they exist, repeat the experiment.

The graph will automatically update for each circuit. In the last tab of the spreadsheet. I am providing measured lengths in this pandemic version. Slopes for determination of the magnetic field are pulled directly from previous tabs here. You will note some columns which are duplicated. This is because I want to indicate how you might show x and y error bars on a spreadsheet but honestly it is not an easy process to show this. Do not resize this graph except after taking a screenshot since this will change the error bars.

For each circuit, you will obtain a slope and an intercept. If you did properly tare the scale at zero current, then the intercept should be almost zero. Otherwise, it will not necessarily be zero.

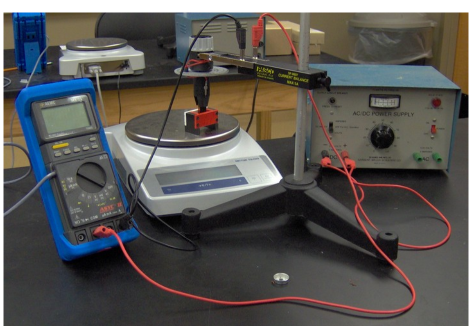
After completing your measurements, enter your length measurements into the current analysis worksheet. The previously calculated slopes are already visible in this sheet. Then run your solver to give the best linear fits again. The slope of this final linear fit will be your magnetic field precisely measured. Here is the theory:

$$F = ILB \quad .$$

For each circuit measurement, you obtained values for LB. Now when you plot L vs F/I the result will be that the slope of this last graph is your magnetic field in Tesla. Typical values for this that I have measured in the past are of the order of about 0.1 T. You will, however, need to make sure you run the solver here also to provide the correct linear fit to your data.

I want for you to notice the impact of errors on the best fit: particularly note what happens if my exaggerated 10% error in the slope is reduced (try reducing it). A good description of results for a linear fit would have the line passing through all data points within the error bars (both x and y error bars).

Part II (I introduced this as the first part of the lab for the pandemic version)



Note: Make sure you tare your scale at zero current.
New Note: your coil must not touch the magnet. You may have to adjust the height of a leg on the ring stand for this to be true. Here is the test: with the current at zero, rotate the spinner through the entire range. The reading on the scale should not change. If it does, it is touching the magnet and the measurement will be bad. However, some of the spinners have a slight magnetic moment so it might be seen that some slight variation is observed in the scale reading even when not touching the magnet.

If a current is not at right angles to the magnetic field, an additional effect becomes important. The magnitude of the cross product holds the key to understanding this. In general, when currents are not perpendicular to a magnetic field, the force is given by:

$$\vec{F} = I\vec{L} \times \vec{B} \quad .$$

If we look at the magnitude of this force, we have:

$$|\vec{F}| = ILB\sin(\theta)$$

where θ is the angle between the current and the magnetic field. In this part of the lab, you are going to verify this sin(Θ) dependence. We have a special attachment which will help with this part of the lab. Place the current balance accessory kit (the spinner) into the current balance and change the magnets. Turn your spinner all the way to the extreme left or till it reads 90 (this is -90 degrees). Then if needed, align the red measurement line right over the 90 mark. This will correspond to 90 degrees. You will make measurements here every 10 degrees, turning the scale from here with a clockwise twist. The current that you use here will be **4.5 A**. As you approach zero, the reading will go like this: -10.0.+10,... .

Note: When you initially set up this portion of the experiment, you should tare your scale at zero current and the placement must be such that the coils inside the magnet freely rotate without changing the scale reading (when zero current is applied). If you don’t make sure of this, you will have significant error in your data.

Your acquisition program (named spinner) will need you to input the angles as you rotate. This program is named spinner:

Here is one final very important note: When you cross zero degrees, you should record the angles as positive angles. Otherwise your acquisition program will seem to duplicate data. (start with -~~90~~ close” and take data every 10 degrees until +90).

You will change the controls on the spreadsheet helper to get the best fit here. There are fine and coarse controls here just in case the computers are too slow (they aren’t). Other than observing the above features and showing that a sin curve does describe the data, there is no additional analysis needed for this portion of the lab. You should realize, however, that the “Amplitude” of the Force Vs Angle curve is given by IBL with I=2.5 A, and L is the total length of wire in the field. Thus, in principle, we could make a measurement of the magnetic field by this method also if we had a good measurement for the wire length in the field. However, this is fairly redundant so we won’t do this. The other fit parameter, the phase, tells you actually the offset from 90 degrees that is experienced. It is a fairly significant parameter also but I have asked you to notice the maximum in the force at right angles and the minimum at zero degrees so further interpretation here is not essential. I have, bowing to pressure from previous years, included the offset parameter in case you did not tare the scale. I hope you won’t need to change this very much at all.

In your analysis you will want to show your understanding of the measurements that you have just done in addition to being able to present a complete analysis of the work. Your write up today should include the last tab on the circuit graph with fit parameters which shows the magnetic field measurement. Also please include the full spreadsheet for the “spinner” results, showing your fit using the solver.

You should write a paragraph (a nice paragraph … with words , sentences, etc.) explaining in your own words each of the parts of the experiment and why (or why not) the expectations were verified.

Ultimately your discussion will tell what you measured, what it verified, and other essential details.

Note: the acquisition program is very similar to my previous programs except for this: when obtaining spinner data, you will need to enter the angle in degrees for each measurement. The data should be in the correct order in your file name under the I directory so that it can be pasted directly into the spreadsheet helper. I have not included screen captures of the acquision programs because I think you will not have problems with this based upon your previous experience. The one difference is for the spinner, you need to enter the angle (-90 (press enter) -80…..).

Summary of proceedure:

Current balance:
Obtain data for sf: 37,38,39,40,41,42
Paste the data into the spreadsheet helper.
Look for obviously bad data. If found, repeat that entire (for that circuit) experiment.
Find the magnetic field. It should be about 0.1 T.

Spinner:
Obtain data for spinner from -90 to +90 every 10 degrees at 2.5 A current.
note: if you enter data for angle incorrectly, you can edit this later.
Paste this into your spreadsheet helper. Change controls to fit phase , amplitude, and offset (If you failed to tare the scale).
Observe that a sinusoidal dependence describes the data.

Your hypothesis is this:

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

But you will need to explain each of the different aspects of this Lorentz force law in your own words: I, L and the angle between IL and B. You should also talk about the direction of the magnetic field here (with regard to positive weight vs. negative weight).