LAKE FOREST COLLEGE

Department of Physics

Physics 115 **Experiment #9: Magnetic Force on a Wire** Spring 2025

Name: Ilana Berlin
Partner: Vy
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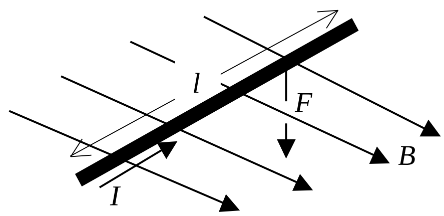
Preliminary Instructions
Create a folder for you and your lab partner on Teams. Save a copy of these instructions for each student to that folder. Include your name in the filename. As you edit this document put your text in a different color. Save one copy of the *Excel* template with both your and your partner's name included in the filename.

Experimental Purpose:
We will study the force on a current-carrying wire that is placed between the poles of a permanent magnet. This force will determine the field of the magnet.

Background:
The force by a magnetic field on a current carrying wire is $F = NIlB$ as long as the current and magnetic field are perpendicular to each other. In this equation, I is the total current flowing through the magnetic field and N is the number of pieces of wire. The length of each piece of the wire that is in the magnetic field is l. The magnitude of the magnetic field is B, measured in Tesla ($1\ \mathrm{T} = 1\frac{\mathrm{N}}{\mathrm{A \cdot m}}$).



There are three parts to this experiment: calibration, measurement, and comparison.

Procedure:
Part I: Calibrate your force transducer

1. Ensure that the cross bar holding the force transducer is horizontal and at the correct height (to hang the wire at the center of the magnet).

2. Start the Logger Pro Software with the Vernier dual range force transducer (10 N scale) connected to the Lab Pro interface.

3. Click on Experiment | Calibrate | CH1 "calibrate now."

4. With only the plastic wire frame hanging from the sensor, enter as "Reading 1" the extra force being exerted on the sensor, namely 0. Click on KEEP.

5. Select a nominally 200 g mass. Use the Mettler balance to measure the mass and then calculate the weight in newtons. **Paste the table here. Include a table caption.**

Calibration

m (g)	Actual Force *mg* (N)
0	0
199.97	1.960

Gravity Field *g* (m/s^2)
9.803

Table 1. Calibration Measurements. The Dual Range Force Sensor was calibrated using a 200g weight. The actual force was calculated using the equation F =mg.

6. Add this weight to the frame using the string at the bottom.

7. Enter as "Reading 2" the force in newtons due to the 200 g mass on the sensor. Ensure the mass is at rest and click on KEEP.

8. Click on DONE. The instrument is now calibrated.

9. Check that the calibration is valid by attaching other weights to the frame with nominal masses of 0, 50 g, 100 g, and 200 g on the force sensor. Weigh the masses and calculate their weights.

10. Hang the masses from the sensor and measure the force exerted on the sensor. The signal is noisy so averaging is required: take data in LoggerPro for several seconds, then use the "Statistics" function to determine the mean and standard deviation of the force data.

11. For each mass, compare the weight to the force measured by the sensor. The standard deviation in the measured force serves as the uncertainty in force measurement. The uncertainty in the calculated weight is much smaller and may be neglected.

12. Use the ratio test to see if the four measured forces agree with the expected results. If so, then your force sensor is calibrated. If not, then repeat the calibration procedure. **Paste the calibration check table here. Include a table caption.**

Calibration check

m (g)	Actual Force *mg* (N)	Sensor Force (N)	Sensor std dev (N)	Ratio Test on Force
0	0	0.001	0.00536	0.19
49.96	0.4898	0.492	0.00528	0.42
100.00	0.9803	0.982	0.00651	0.26
199.97	1.960	1.964	0.00903	0.41

Table 2. Calibration Check. Actual force was calculated using the equation F = mg. Sensor Force and Sensor standard deviation were read off average measurement of dual range force senor with added mass. All values agree according to the ratio test.

Part II: Measure the magnetic force as a function of current

13. Place the frame so that the bottom of the loop is in between the poles of the permanent magnet. Be sure the frame of the wire is level and parallel to the magnet poles. Draw a schematic of your experimental setup. **Paste the drawing here. Include a figure caption.**

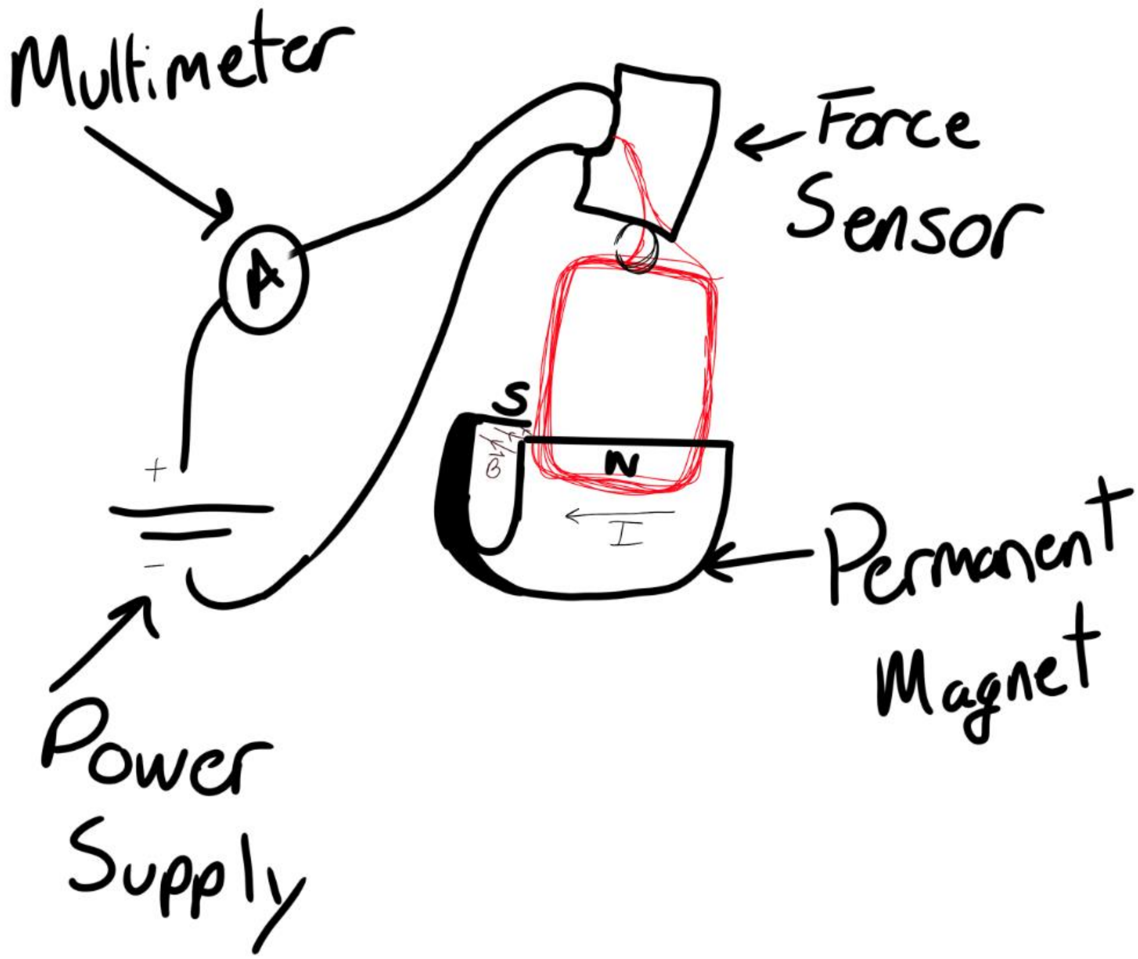


Figure 1. Apparatus Diagram. Topward power supply provides current to the wire. The permanent magnet creates a magnetic field around the wire from the north pole to the south pole. The Dual range force sensor measures the magnitude of the force on the wire.

14. Record the output from the force transducer with current flowing through the loop. Do not exceed 6 amps of current. *Do not leave the current on any longer than necessary—otherwise the wires in the coil will overheat.*

15. Check that larger positive currents give larger readings of the force sensor. This means that the magnetic force on the wires is downward. Reverse the magnet if necessary.

16. Measure the current with a Fluke 75 DMM; do not rely on the meter built into the power supply.

17. Record the average force for at least five different currents from 0 to 6 A.

18. Reverse the wires at the power supply and record two data points with small negative currents such that the magnetic force on the wires is upward. You need to keep the magnitude of the current small (<1.5 A) so that the magnetic force is much less than the gravitational force, or else the loop will tilt. **Paste the table here. Include a table caption.**

Force on Wire

Current (A)	Force (N)
0	0.0196
1.00	0.122
2.02	0.247
3.05	0.360
4.02	0.471
5.00	0.582
6.00	0.697
-0.51	-0.0362
-1.01	-0.0925

Table 3. Current vs Force Measurements. The current was provided by a topward DC power supply and measured by a Fluke multimeter. When the current was positive there was a positive, downward, force on the wire. When the current was negative, there was a negative, upwards, force on the wire. The higher the amps of the current, the more force there was on the wire.

19. Plot the measured force F (in N, on the y-axis) as a function of the current I (in A, on the x-axis). The data should fall on a straight line. Fit the data to a linear function and determine the slope of the line and the uncertainty in this slope. **Paste the graph here. Include a graph caption.**

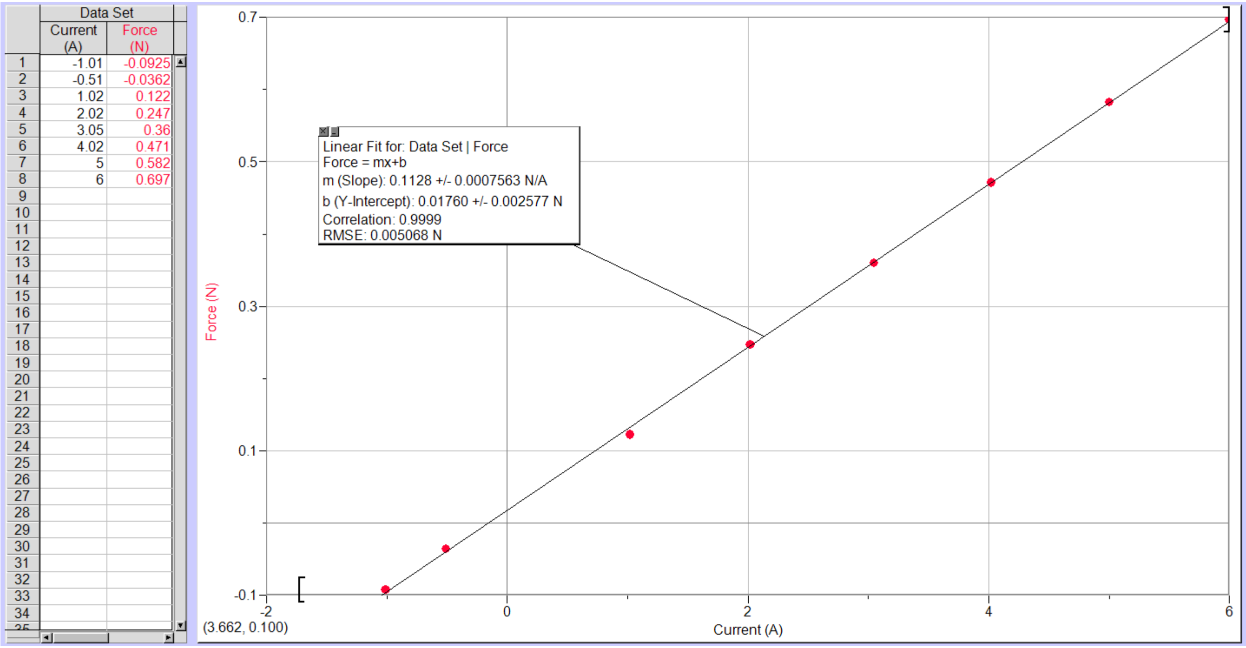


Figure 2. Force vs Current Graph. Current, in amps, is on the x-axis. Force, in newtons, is on the y-axis. The slope of the line represents the NlB of the force equasion F=NlBI + F_o.

20. Measure the length of the wire (l) that is in the magnetic field. (*Measure the length of the horizontal section of the wire, not the plastic frame*.) Estimate the uncertainty in this length as 3 mm. **Paste the table here. Include a table caption.**

21. Carefully count the number of turns of wire (N). Note that not all of the frames have the same number of turns.

22. Use your slope from step 19 and the measurements of l and N to determine the magnitude of the magnetic field between the poles of your permanent magnet. Combine the uncertainty in the slope and the uncertainty in the length to determine the uncertainty in the magnetic field. **Paste the table here. Include a table caption.**

Field determination from force

	Slope (N/A)	*N*	*l* (m)	*B* (T)
Value	0.1128	10	0.07282	0.1549
Abs Unc	0.008	0	0.003	0.02
Rel Unc (%)	6.7%	0.00%	4.1%	10.82%

Table 4. Calculated Magnitude of Magnetic Field. N is the number of loops of wire. L is the length of the wire in the magnetic field. B is the magnitude of the magnetic field. B was calculated using the equation B = m/Nl where the slope m = NlB.

Part III: Measure the field of the magnet with the hand-held gauss-meter.
NOTE: Do not start this section until you have completed the analysis of Part II.

23. Place the probe in the zero-Gauss chamber (very low magnetic field) and zero the meter.

24. Place the tip of the probe between the poles of the permanent magnet at the locations where the wire was positioned.

25. For a given position in the magnet, adjust the orientation of the probe to find the maximum reading: after the probe is in place, use the “Max Hold” feature, which will display the maximum value of the field as you rotate the probe slightly. Repeat this procedure at several positions within the magnet corresponding to the location of different pieces of the wires. (Use “Max Reset” to clear the previous maximum value.)

26. Calculate the average magnetic field along the wire’s location and use the standard deviation of your measurements as the absolute uncertainty in this magnetic field. **Paste the table here. Include a table caption.**

Reference

Location in Magnet	Gauss-meter *B* (T)
1	0.152
2	0.153
3	0.1538
4	0.153
5	0.1539
Average	0.15314
Std Dev	0.0008
Rel Unc (%)	0.50%

Table 5. Measured Magnitude of Magnetic Field. The field was measured using a Lakeshore gaussmeter. The gaussmeter was zeroed in a zero gauss chamber. The magnetic field was measured at 5 places between the poles. Max hold was used to find the maximum magnitude.

27. Compare this measurement of the magnetic field (Part III) to the value found in Part II using the ratio test. **Paste the table here. Include a table caption.**

Comparison
Ratio Test on *B* II & III
0.101

Table 6. Calculated vs Measured Magnetic Field Comparison. The calculated values was calculated using the equation B = NlB/Nl and the measured values was measured using a lakeshore gaussmeter. The two values agree according to the ratio test.

Discussion Questions:

1. Explain why $\text{slope} = NlB$ in the graph of step 19.

The slope is NlB because that is the coefficient of I that determines the force. Force is calculated using the equation $F=NlBI+F_o$ and the linear fit equasion is y=mx+b. x is the current, I, and y is the force, F, so m is NlB and b is F_o.

2. Why can we ignore the magnetic forces on the vertical wires in the frame?

We can ignore the forces on the vertical sections of wire because the current is moving in opposite direction on either side, so the two sides cancel out.

3. Can the horizontal wires at the top of the frame influence the field determination? In what way?

Because there is a difference in the magnitude of the magnetic field acting on the top and the bottom of the loop of wires, there is a force exerted on the wire. If the top wires were also in the magnetic field, then there would be not force on the wire because everything would cancel out.

Conclusion:

Briefly summarize what you conclude from the results of your experiment.

A force is exerted on wire with a length of 0.0728±0.003m and 10 loops when it is partially inserted into a magnetic field. The magnitude of the magnetic field can be measured using a gaussmeter or calculated using the force exerted on the wire at varying amplitude. For this experiment, the measured magnitude was 0.1531±0.0008T and the calculated value was 0.1560±0.017T. These values agree according to the ratio test.

Final remarks

Adjust the formatting (pagination, margins, size of figures, etc.) of this report to make it easy to read. Save this report as a PDF document. Upload it to the course Moodle page. Ensure that your Excel file, Logger Pro file, and all pictures are saved to the Team.

Clean up your lab station. Put the equipment back where you found it. Remove any temporary files from the computer desktop. Make sure that you logout of Moodle and your email, then log out of the computers. Ensure that the laptop is plugged in. Check with the lab instructor to make sure that they received your submission before you leave.