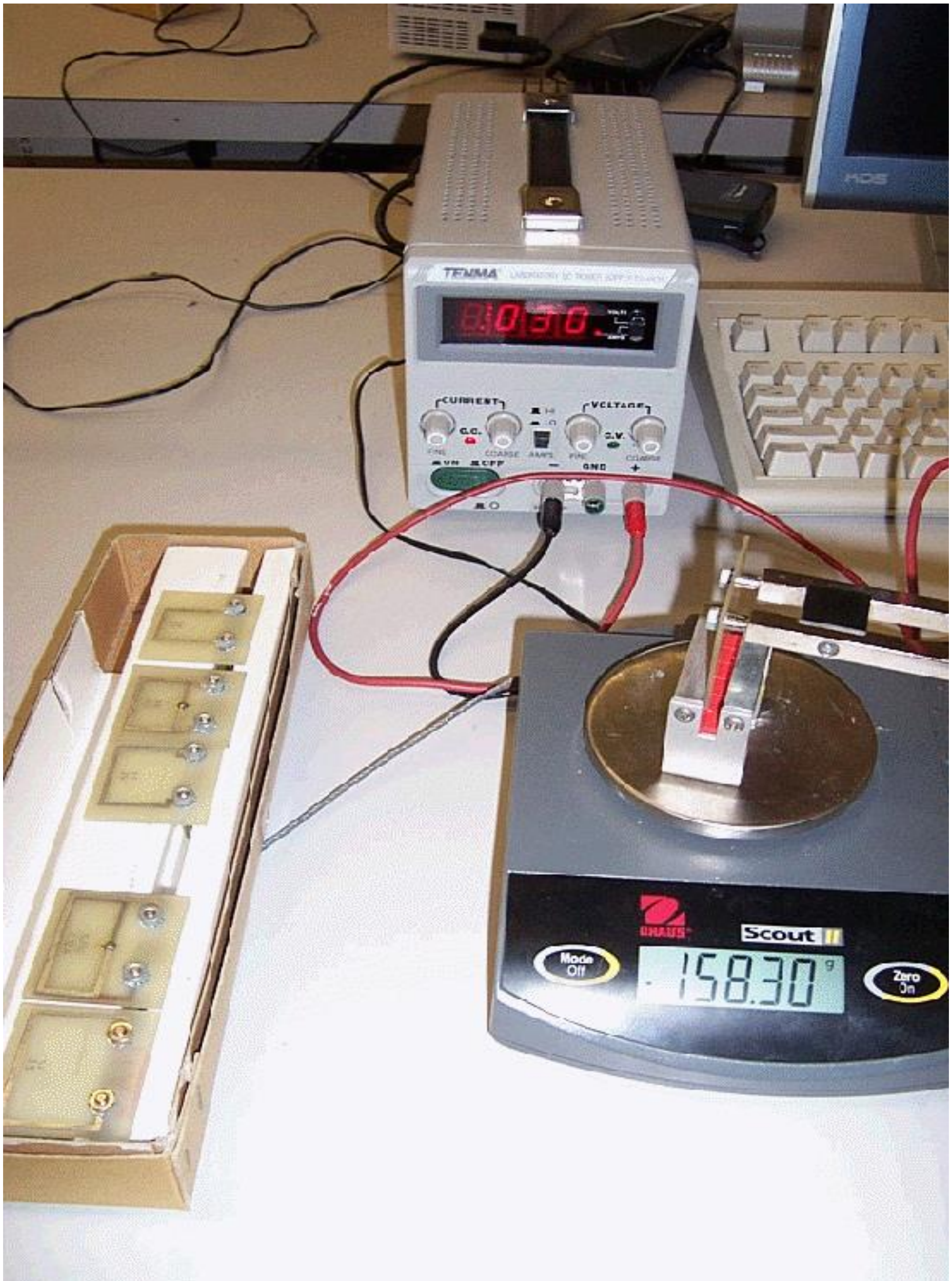
Magnetic Force



<u>Force on a magnet due to a current carrying wire</u>

In this lab you will investigate one possible method of measuring the forces that a magnet and a current carrying wire exert on each other. Remember that the force exerted by a magnetic field on a charge with velocity **v** is given by:

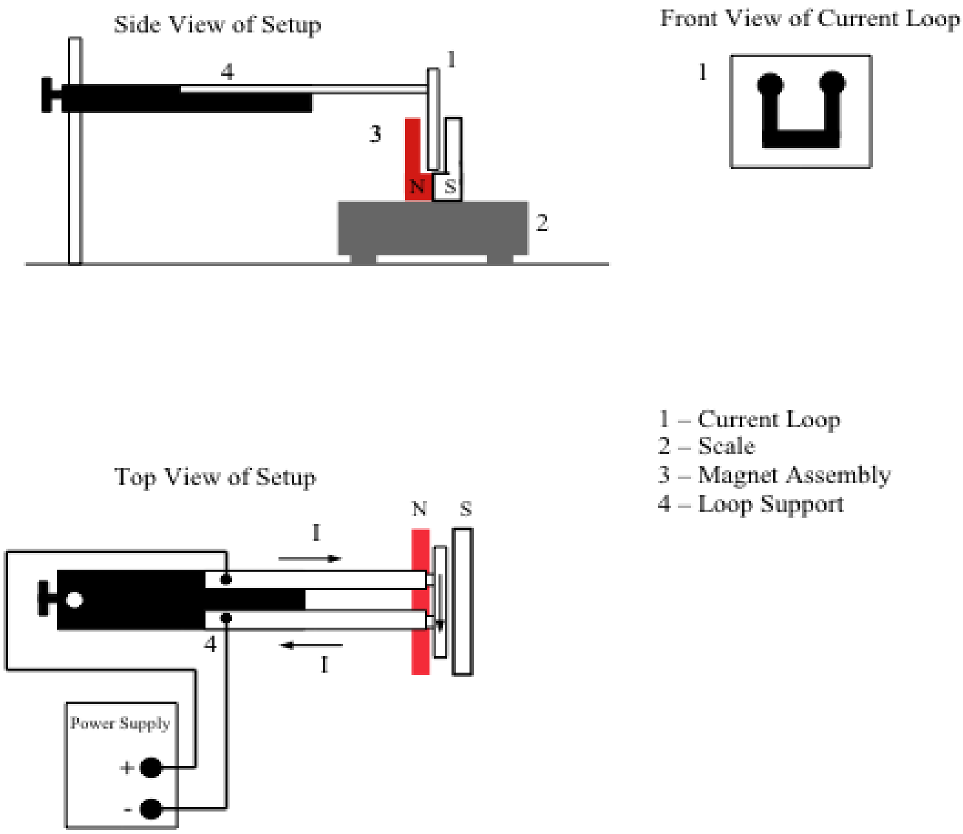
$$F = qvxB$$

Likewise, the force exerted by a magnetic field on a current-carrying wires is:

$$F = ilxB$$

where i is the current and **l** is a vector whose length is the wire segment in consideration and whose direction is in that of the current's.

You have a horseshoe magnet whose poles are known (Red: North, White: South), a scale, and a wire through which a current can flow, a voltage source and connecting wires:



Setup Figure

Part I: Qualitative testing of the right-hand rule (35 pts)

Choose any one of the current loops and assemble the system precisely as shown in the Setup Figure. That is, connect the power supply and keep the orientation of the magnets exactly as shown in the figure. Do not, however, turn on the power supply yet.
DO NOT ZERO THE SCALE AFTER YOU PLACE THE MAGNET ASSEMBLY ON IT. In addition, you should place the center the current loop well within the groove of the magnet assembly, however, do not let the current loop fiber board touch the magnet assembly.

a) Based on your setup, how should the apparent "weight" of the magnet assembly (when the power supply is ON and current is flowing through the current loop) compare to the true "weight" of the magnet assembly (when the power supply is OFF and there is zero current flowing through the current loop)? Explain your reasoning in terms of the right-hand rule. **Note that you will <u>not</u> be penalized for a wrong answer or explanation, because can correct that in part (b) below.**

Hint: Your answer will depend on the direction of the magnetic force exerted on the magnetic assembly by the current loop. You may find it easier, however, to first determine direction of the magnetic force on the horizontal portion of the current loop due to the magnet assembly and then, using Newton's 3rd Law, determine the direction of the magnetic force on the magnetic assembly. Draw free-body diagrams of the horizontal portion of the current loop and the magnet assembly as part of your explanation. (10 pts)

b) Turn on the power supply, put both COARSE and FINE Voltage knobs to mid-position and increase the current to the maximum possible allowed by the power supply. Describe what happens to the reading of the scale. Does the result agree with your prediction? If not, explain why. (5 pts)

c) Turn off the power supply and reverse the electrical connections on the loop support. How should the apparent "weight" of the magnet assembly compare to the true "weight" of the magnet assembly now? Again, explain your reasoning in terms of the right-hand rule. Draw free-body diagrams of the horizontal portion of the current loop and the magnet assembly as part of your explanation. (10 pts)

d) Turn on the power supply and increase the current to the maximum possible allowed by the power supply. Describe what happens to the reading of the scale. Does the result agree with your prediction? How does it compare to the reading from part (b)? (5 pts)

e) In the preceding analysis we have ignored the interaction between the magnet assembly and the two *vertical* portions of the current loop. (Did you notice this?) Explain why the vertical portions of the current loop do not contribute to the magnetic force between the current loop and magnet assembly. (5 pts)

Part II: Investigate (quantitatively) how the force exerted by a magnet on a current carrying wire depends on the magnitude of the current. Determine the magnetic field of the the magnet assembly. (30 pts)

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

Select one of the current loops and record the length of the horizontal portion (see table above). (You may use the current loop that you're already using!) Reassemble the apparatus as in the Setup Figure. **Using the same current loop for this activity**, record the magnetic force for at least 6 different positive values of the current over the full range of current. Note: The magnetic force is the *difference* between the apparent "weight" and the true "weight". Also, remember that the scale measures mass in grams. You must properly convert this mass to force. **REMEMBER NOT TO ZERO THE SCALE <u>AFTER</u> THE MAGNET IS PLACED ON IT – JUST RECORD THE BASE VALUE AND NOTE THE DIFFERENCE BETWEEN THE SCALE READING AND THIS BASE VALUE.**

Reverse the electrical connections <u>on the loop support</u> after your last data point. What does this do to the current, and hence the force on the scale? Then, keeping the connections on the loop support reversed, now reverse the electrical connections <u>on the power supply</u> – what happens now?

a) What do you observe about the direction of the force, after you reversed the connections on the loop support (or reversed them on the power supply)? (5 pts)

b) What is the equation that relates the magnetic force to the current through the loop and other quantities? Based on the 6+ data points you took before reversing the connections, is the relationship between the magnetic force and current linear? Is it quadratic? Is it exponential? (15 pts)

c) Plot the magnetic force vs. the current using Logger Pro. Make sure your plot has a title, axes labels with units, and a best fit. Use your plot and the equation you wrote down in part a) to determine the magnitude of the magnetic field of the magnet assembly. Show all work. (10 pts)

Hint: If you look at the ***F*** = ***il*** *x* ***B*** equation, you'll notice that in this activity you will only be varying one quantity on the right side. What about the other quantities – *are they variable or constant, meaning do they change in this activity?* (rhetorical question). If any of them are constant, consider rewriting the equations with a parenthesis that groups them as a coefficient that goes right before the independent variable, which you will be varying. You can then try to think of what this coefficient represents in light of the expected (theoretical) dependence of the Force on the quantity you are varying.

NOTE ON UNITS:

The equation $F = ilxB$ has Force in Newtons, Current in Amps, Length in Meters, and Magnetic Field in Tesla. *These are all MKS (Meter-Kilogram-Second) units.*

You may also use Force in Dynes, ***Current in Ab-amperes (0.1 of an Ampere),*** Length in Centimers, and Magnetic Field in Gauss (1 Gauss = 0.0001 Tesla). *These are all CGS (Centimeter-Gram-Second) units.*

You should be consistent with your units; use only MKS **or** only CGS.

If your answers for ***B*** are off by a factor of 10, 100 or a 1000, check to see if you've used inconsistent units, or if you've omitted the acceleration due to gravity, or forgotten to convert g to kg, etc.

Part III: Investigate (quantitatively) how the force exerted by a magnet on a current carrying wire depends on the length of the wire. Determine the magnetic field of the the magnet assembly using a second method. (35 pts)

Select one of the current loops and record the length of the horizontal portion of the current loop. Assemble (again) the apparatus as in Setup Figure. Turn the current to its maximum possible value (record this value of current) and record the magnetic force. **AGAIN, REMEMBER NOT TO ZERO THE SCALE AFTER THE MAGNET IS PLACED ON IT – JUST RECORD THE BASE VALUE AND NOTE THE DIFFERENCE BETWEEN THE SCALE READING AND THIS BASE VALUE.**

1. Devise an experiment to determine how the magnetic force on the horizontal part of the current loop depends mathematically on the length of that segment. Rhetorical question: how will you vary the length of the segment? **Hint: you only have have a discrete number of segments on your lab table.** Make sure you state in your lab report: your plan and its steps, your graph - clearly and completely labeled - your curve fit and analysis (using either Google Docs, Excel or Logger Pro). (20 pts)

2. Use your plot and curve fit to find the field strength of the magnet - in Teslas (MKS) or Gauss (CGS). You did the same in Part II, but from a different method. (10 pts)

Hint: Same as the one in Part II.

3. How do your two measurements - from Part II and Part III of the magnetic field compare to each other? Rhetorical question: which method do you think is more ***precise***? A typical refrigerator magnet (the one used to post sheets of paper on a refrigerator) has a magnetic field on the order of 100 Gauss (1 Gauss = 0.0001 Tesla). How does your value compare to the fridge magnet's? (5 pts)