Magnetic Balance

Purpose

The purpose of this experiment is to determine the strength of a magnetic field by measuring the force it exerts on a current carrying wire.

Theory

When a wire carries a current in a magnetic field, the interaction between the magnetic field and the current results in a force given by:

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

$$F = I\left|\vec{L}\right|\left|\vec{B}\right| sin\theta$$

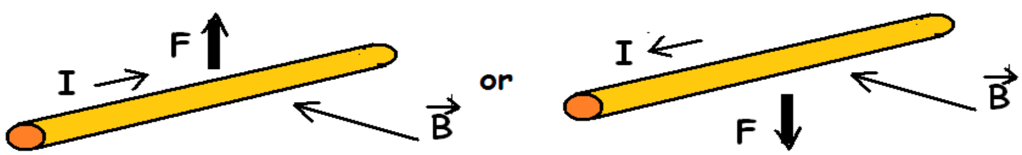

Figure 1. Magnetic force on a wire

When I is the current in the wire [units: Amperes], B is the magnetic field strength [units: Tesla], and L is the length of the wire [units: meters] and F is the force exerted on the wire [units: Newtons]. The angle between $\vec{L}$ and $\vec{B}$ is θ.

The right hand rule can be used to determine the direction of the force when the direction of the direction of the current and the magnetic field are known. **Check that you can use the right hand rule to verify the orientation of the forces in Figure 1.**

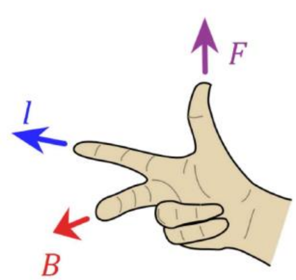

Figure 2. Right hand rule

In this experiment, a wire will be held in a fixed position, while the magnet will be placed on a balance. The magnet assembly will be subject to the force of gravity, mg, and also to the magnetic force, F, due to the interaction of the field and the current carrying wire. The current in the wire can be adjusted to change the magnitude of the force exerted on the magnet which will change the reading on the balance.

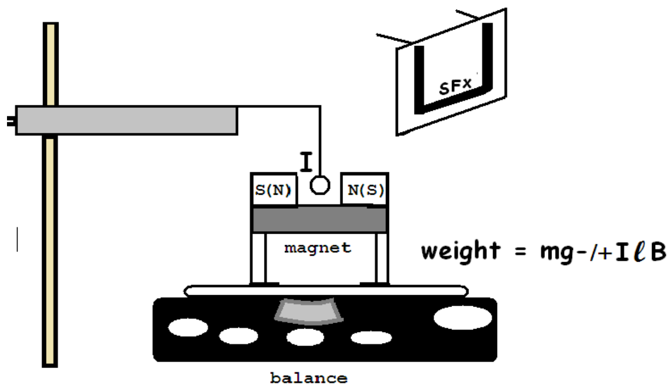

Figure 3. Setup for Magnetic Balance

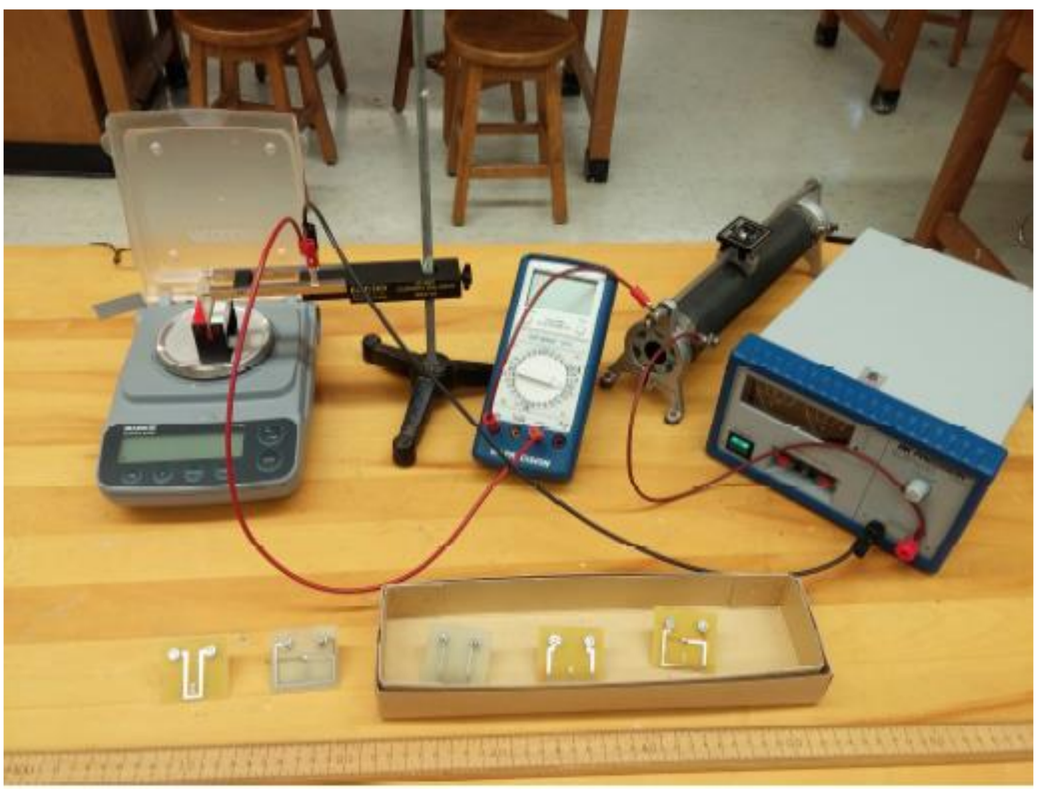

Figure 4. Picture of the setup for Magnetic Balance

The magnetic force (F) actually depends on four variables:
• the current in the wire (I),
• the length of the wire (L),
• the angle between the wire and the magnetic field (θ),
• the magnetic field strength (B).

while the gravitational force depends on:
• the mass of the system (m)
• the gravitational acceleration (g).

The downward force on the balance, "weight" W is then described by:

$$W = mg \ \pm ILBsin(90^o)$$

Therefore, plotting W (mass multiplied by g = 9.8 m/s^2) vs. $IL\sin(90°)$ gives:

$$slope = \ \pm B$$
$$y\ intercept = mg$$

Procedure

1) Choose three wire loops and look-up their lengths in Table 1 (next page). Don't forget to record the circuit numbers.
2) Turn on and zero the balance.
3) Record the magnet number and place it on the balance.
4) Take one of the current loops and complete the setup as shown in Figure 2. Adjust the current loop so that it is located between the poles of the magnet. Make sure the loop is within the magnet and does not touch it.
5) Using the power supply control, set the current in the 0.5 A to 3.0 A range and record the weight and the current for 6 points in the worksheet.
6) Repeat this procedure for the other two current loops.

Analysis

1) Plot a suitable graph for each wire segment and use each graph to determine the magnetic field strength.
2) Compute and average $\bar{x}$ and the standard deviation σ of the magnetic field strength.

$$\bar{x} = \frac{\sum_k x_k}{n}$$

$$\sigma = \sqrt{\frac{\sum_k (x_k - \bar{x})^2}{n-1}}$$

3) What is the percentage uncertainty $100 * \frac{\sigma}{\bar{x}}$ of your measured value of B? Would you consider this experiment to be precise? Explain.

4) Does the provided magnetic field strength (90 mT) fall within the range of $\bar{x} \pm \sigma$? If not, how many standard deviations away is it? Based on this, do you believe the provided value?

5) Is the y-intercept of each plot consistent with each other? Why or why not?

Circuit	Length
SF37	2.20 ± 0.07 cm
SF38	4.20 ± 0.07 cm
SF39	3.20 ± 0.07 cm
SF40	1.20 ± 0.07 cm
SF41	6.40 ± 0.07 cm
SF42	8.40 ± 0.07 cm

Table 1: Lengths of wire segments

Worksheet

Circuit #	
Length (cm)	
Current (A)	Weight (N)

Circuit #	
Length (cm)	
Current (A)	Weight (N)

Circuit #	
Length (cm)	
Current (A)	Weight (N)