Experiment 22
The Current Balance

Advance Reading:
Physics 4th Ed by Randall Knight
Chapter 29, Sections 29.1 to 29.4

Equipment:
1 Pasco Current Balance apparatus
1 digital balance
1 power supply
3 double-banana plug wires.
1 Kelvin DMM
1 table clamp
1 short rod

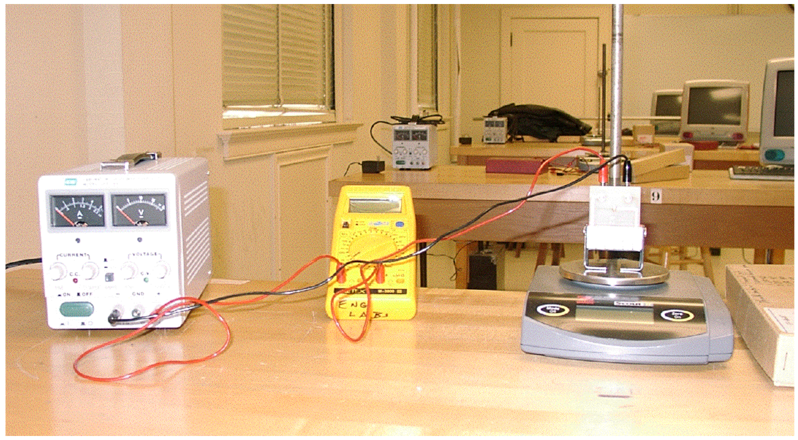

figure 22-1

Objective:

The objective of this lab is to measure the effects of a magnetic field on a current carrying conductor (wire) by selectively varying a number of parameters.

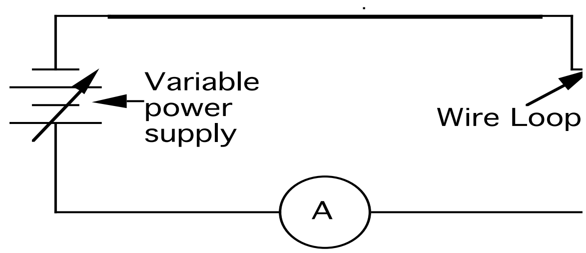

Figure 22-2 Circuit diagram

Theory:

A magnetic field **B** exerts a force $\mathbf{F}_B$ on a moving positive charge that is given by the vector cross product

$$\mathbf{F}_B = q\mathbf{v} \times \mathbf{B} \qquad \text{(Eq-1)}$$

where q is the charge, **v** is the velocity of the charge and **B** is the magnetic field.

The magnitude of this force is given by

$$F_B = |q| vB \sin\theta \qquad \text{(Eq-2)}$$

where θ is the smaller angle between the velocity vector **v** and the magnetic field vector **B**.

Since a current is a collection of charges in motion, a magnetic field should also exert a force on a current carrying conductor (wire). The magnitude and direction of this force is dependent upon four factors: (1) the length of the wire, (2) the strength of the magnetic field, (3) the magnitude of the current, and (4) the angle between the field and the wire.

The magnetic force $\mathbf{F}_B$ in this case is given by the vector cross product

$$\mathbf{F}_B = I\mathbf{L} \times \mathbf{B} \qquad \text{(Eq-3)}$$

where I is the current, **L** is a vector that points in the direction of the current and has a magnitude that is equal to the length of the segment (i.e., length of the wire) and **B** is the magnetic field.

The magnitude of the magnetic force in Eq-3 is given by

$$F_B = ILB\sin\theta \qquad \text{(Eq-4)}$$

Procedure:

Part 1: Force vs. Current

1. Set up the apparatus as it appears in figure 22-1 and figure 22-2 using the current loop numbered SF 42. The circuit consists of a power supply, an ammeter (DMM) and the wire loop all connected in series.

2. Place the long magnet on the center of the balance pan. The wire loop should be arranged so that it passes through the pole region of the magnet (i.e., the horizontal part of the wire is just below the top of the magnet). See Figure 22-3 below.

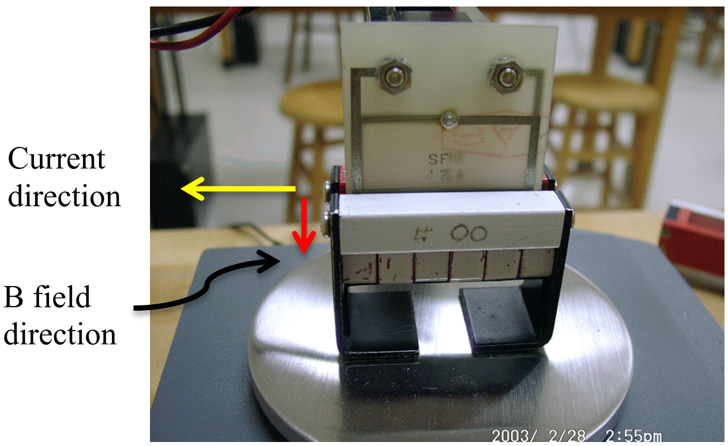

Figure 22-3
(Red arrow direction is to front of magnet)

3. **With no current flowing zero the balance.** *This is your zero magnetic force since there is no current flowing.*

Once the experiment starts, **do not move the setup.** It is also important to keep all metal objects and wires away from the magnet. These could affect the data.

4. **Before plugging in the power supply, have your instructor check the circuit.** After it has been approved, plug in the power supply and adjust the dial until the DMM reads approximately 1.0 amps. *When the current is turned on, the magnet should be pushed downwards and the mass should increase.* **If the balance reads less than before (i.e., negative), reverse the wires on the arm of the current balance.** The increase in mass with the current on is due to the magnetic field. Calculate the magnetic force (multiply mass by g).

5. Increase the current in one-amp increments until 5.0 amps is reached. Record the current and the ‘magnetic mass’ for each step. Convert mass to force. Using **Graphical Analysis** plot magnetic force vs. current and then determine the best-fit line. **Be sure and include (0,0) data point.** From the slope you will determine the magnetic field strength of your magnet.

Part 2: Force vs. Length of Wire

6. For this part of the lab you will need to know the effective length of the wire loops. They are as follows:

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

Note that the numbers on the loops do not signify the length of the wire.

Insert the shortest wire segment (SF 40) into the holder. Measure the mass of the magnet holder and the magnets again and determine its weight. (It should be about the same as before).

7. Adjust the power supply until the DMM reads 2.0 amps. Determine the magnetic force. Repeat for all six (wire) loops. Plot magnetic force vs. wire length. **Be sure and include (0,0) data point.** From the slope you will determine the magnetic field of your magnet.

Part 3: Force vs. Angle

8. Plug the round Current Balance Accessory into the arm of the current balance. Replace the long magnet assembly with the small “square” magnet. See Figure 22-4. **Zero the balance.**

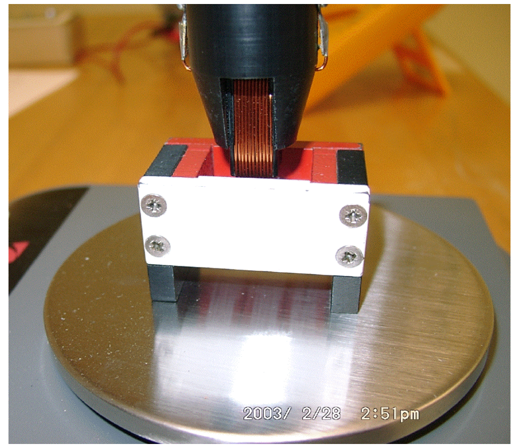

Figure 22-4

9. Set the angle to 0^{o} by aligning the direction *of the horizontal portion* of the coil wire so that it is parallel to the direction of magnetic field. See Figure 22-5. Set the current to 2.0 amps.

Figure 22-5

If the mass changes, slightly rotate the digital balance so that the mass returns to zero. This force is your zero (angle) force, which is zero since sine of zero is zero.

10. Increase the angle in 10^{o} increments up to 180^{o}. **At each angle (record) the mass measurement and convert to force.** Plot magnetic force vs. angle. From this plot, determine the strength of the “square” magnet.

Questions (Show all work):

1. The magnetic field B of the magnet in this experiment can also be determined by solving for B in Eq-4 and making one measurement.

Rewrite Eq-4 in terms of B and calculate the uncertainty of a single measurement.

This single measurement is the first measurement made in step 5.

Assume the uncertainty of the length L (of SF 40 wire) is 0.01 cm. Assume uncertainty of a current of 1.00 amp is one digit and the uncertainty of magnetic force F_B is 0.0001 N. *Assume uncertainty in sin(90 degrees) is negligible.* Make sure all units are in SI units.

2 . In parts one and two of the experiment you ignored the lengths of the vertical segments of the wire that run down into and out of the magnet. *Why do you consider only the single horizontal segment of wire?* This is true regardless of position of the

3. Looking at figure 22-3 draw free body diagrams (for magnet) for the following two cases:

a) The weight (mass) of digital balance increased when current was on.

b) The weight (mass) of digital balance decreased when current was on.

4. The magnetic fields you calculated in parts 1 & 2 above should have been the same when uncertainty is considered.

Using the uncertainty calculated in question # 1 as the uncertainty of both magnetic fields, rewrite the measurements from parts 1 & 2 with the uncertainties (i.e., $\boldsymbol{B} \pm \boldsymbol{\delta B}$ for both parts)

Discuss whether the two values were the same (i.e., do the values overlap). If not discuss errors. Show all work.