Name: ____________________

Partner(s): ____________________

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Date: ____________________

Current Balance

Purpose

In this lab, you will examine the interaction of two current carrying wires.

Significance

The ampere, in the MKS system of units, is defined in the following way: "One ampere is that unvarying current which, if present in each of two parallel conductors of infinite length and one meter apart in empty space, causes each conductor to experience a force of exactly $2x10^{-7}$ Newton per meter of length." The current balance, Figure 1, is a delicate instrument that is used to measure the magnetic force between current-carrying conductors, allowing us to make this fundamental measurement.

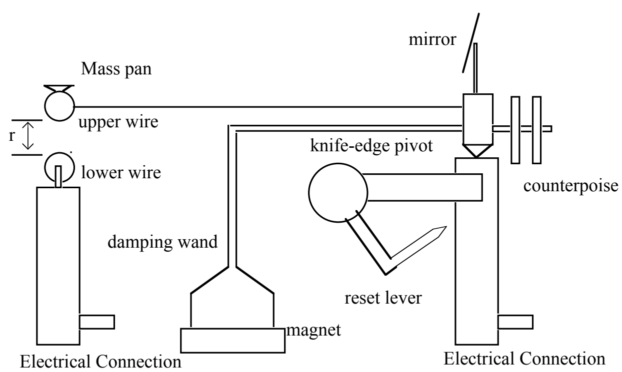

Figure 1: Side view of the Current Balance (Not to scale)

Theory

The current balance consists of two parallel wires of length L, separated by a distance r. When properly connected to a power supply, a current, I_l, will flow in one direction in the lower wire. A current, I_u, will flow in the opposite direction in the upper wire. In the space below, describe, physically, how the current balance allows us to use the definition of the ampere to check the calibration of an ammeter.

Let's now put into symbols what you described above. What is the force that a wire, carrying current I, experiences in a magnetic field B?

What is the magnetic field created by a wire carrying current I?

From this, show that the force on the upper wire is given by Equation 1.

$$F = \frac{\mu_o L I^2}{2\pi r} \qquad (1)$$

Procedure

In this lab, we will be exploring the interaction between two current-carrying wires by examining the relationship between the interaction force and the current.

The lower wire is fixed, while the upper wire is free to rotate about the knife-edge pivot, as seen in Figure 1. Obviously, it is going to be very difficult to directly measure the location of the upper wire directly. Not only are the separation distances small, the apparatus is very sensitive to disturbances. However, we can determine the location of the upper wire using a laser.

You will notice that the upper wire is connected to a knife edge pivot by a small rod of length b. Connected to the pivot is a mirror, which will rotate with the wire. By shining a laser beam on the mirror, you can project the laser beam on the wall, a distance a from the mirror. This will allow us to measure the location of the upper wire with much greater resolution: larger values of a will lead to higher resolution.

Part 1: Force and Current

In the first part of this lab, you will examine the relationship between force and current.

Before you can begin, you will need to connect the upper wire and lower wire in series to the large power supply at your station. Additionally, the power supply should be at least $^{3}/_{4}$ m from the current balance. After you have completed the electrical connections, have your instructor or TA examine your setup.

After your setup is wired, you need to make sure that the knife pivot is located in a reproducible location. This is easily done using the *reset lever*. Under the knife pivot, there are two small holes that will line up with the screw on the reset lever. Line up the screws on the reset level with the holes under the knife pivot and gently twist the reset level until the knife pivot is suspended above the current balance. Once this is done, gently return the reset level to its original location, such that the knife pivot is again resting on the apparatus.

Before you can begin taking your data, you need to adjust the balance so that the wires can *not* touch, even at low currents. To do this, place the largest mass that you will be using, 50 mg in this part of the lab, on the mass pan located on the upper wire. Adjust the counterpoise until the wires are close, but not touching. A wire separation of about 0.5 mm should do nicely. Once there is an appropriate wire separation, remove the 50 mg mass. Once the apparatus has stopped oscillating, the location of the spot produced by the laser beam on the wall is a reference position that indicates the wire separation where the net torque on the upper wire is zero.

To examine the relationship between force and current, you will add a known mass to the mass pan on the upper wire and increase the current until the laser beam returns to the reference position. In the space below, draw the force body diagram of the upper wire, once it has been returned to its reference position. How is the force due to the magnetic repulsion related to the force of gravity on the mass? (*Hint*: Why do you not have to consider the mass of the upper wire?)

You will take data for a variety of masses, from 0 to 50 mg. After you have placed a mass on the mass pan, adjust the current until the laser beam has returned to its reference position. The apparatus will heat up as a current flows through it, causing the beam to drift as the wire expands. As such, you will need to return the laser beam to the reference beam quickly. You can limit the heating by smoothly adjusting the current to avoid large oscillations and by turning the power supply off between measurements, especially at larger currents.

Do ***NOT*** let the current exceed 10 A. You can record your data below.

Mass ( )	Current ( )
0	
50	

Does the direction of the current matter? If so, explain why and take whatever data is relevant to account for this.

Plot your data. Discuss why you chose the axes that you used.

What type of functional relationship do you see? Does this agree with your expectations from the beginning of the lab? Perform any relevant analysis and attach it to the lab manual.

It is always nice when you examine your data to do more than simply compare its functional form to your model. One way to check your data in an absolute sense is to extract, from your fit, a parameter or constant, whose value is known. In this case, you should be able to extract a value for the constant μ_o. In the space below, determine, from your data, a value for μ_o? Describe any measurements that you had to make and clearly show all calculations.

How does this value compare with the accepted value?

Questions

1. When the current is reversed, why doesn't the force become attractive, *i.e.* why isn't the upper wire pulled down?

2. Why does the power supply need to be far from the current balance? *Hint*: If the power supply is near the computer monitor, you may have noticed that the picture was distorted. Why?

3. ***Calculate*** the mass of the counterpoise?

Initiative

Possible ideas:

1. How could you determine the functional relationship between force and the separation distance, *d*, of the two current carrying wires using only the current balance apparatus and a single, say 50 milligram, mass? Do not perform an experiment, just describe how you would accomplish this.

Conclusions