CURRENT BALANCE

OBJECTIVE

To use the current balance to measure the mechanical forces exerted by electrical currents.

INTRODUCTION

If a current *I* passes through an infinitely long straight wire, the resultant magnetic field produced outside the wire is given by

$$B = \mu_0 \frac{I}{2\pi\, d} \quad , \tag{1}$$

where *d* is the radial distance from the center of the wire and μ_0 is the permeability of free space. If a second wire of length *L* carrying the same current is placed parallel to the first wire it will experience a force given by

$$F_A = BIL = \mu_0 \frac{LI^2}{2\pi\, d} \quad . \tag{2}$$

Here, *d* is the distance the centers of wires. If the two currents are in opposite directions, then the two conductors will repel one another.

EQUIPMENT

CB apparatus, multimeter, analytical balance, laser, blocks, weights, leads.

Fig. 1.

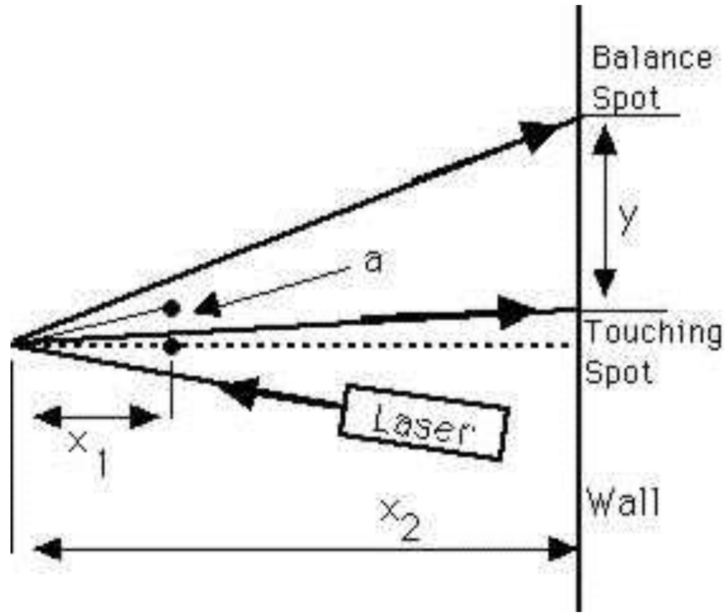

Fig. 2.

a = edge-to-edge distance between the wires

X_1 = distance between the pivot and the current carrying

X_2 = distance between the pivot and the wall

PROCEDURE

Before the power supply is turned on, have your instructor inspect the circuit.

Step 1: Adjust the bars of the balance to be parallel using the thumb-screws on the supports. Adjust the counterbalance so that the bars are approximately **2 mm apart.**

Step 2: Connect the circuit shown in the photograph **keeping the power supply off.** Adjust the light source and counterbalance on the current balance so that the image from the light source is projected on a convenient place (see fig.2). The beam should be approximately horizontal. Record the position of this **balance spot** on a fixed sheet of paper attached to the wall. **Have your instructor inspect the circuit**.

Step 3: Prepare two masses m_1 and m_2 in the range of **6mg to 8mg** and **9mg to 11mg** respectively. Electronic analytical balances are on the instructor's desk to determine the exact weight.

Step 4: Place one small weight on the upper beam of the current balance**.**

Step 5: Turn on the power supply. Slowly increase the current until the light spot rises back to the balance point**. Record the current**: This will be the **forward current**. Turn the current adjustment down and turn off the power supply.

Step 6: Reverse the power supply connections. Turn on the power supply and adjust the current to bring the light beam back to the balance spot again. Record this **reverse current**.

Step 7: Repeat steps 4-6 with the larger weight and again with **both** weights together on the upper beam.

Step 8: Measure the length of the current carrying wires *L* (only over the region where they are parallel and close to each other).

Step 9: Measure X_1 and X_2 from the actual pivot point.

Step 10: Bring the two conductors together until they touch. Mark the location of the light beam on the sheet of paper attached to the wall. Record the distance between this "**touching spot**" and the "**balance spot**" marked above. This is labeled "y" in the figure.

GRAPHS AND DIAGRAMS

Plot the force the two wires exert on one another versus the product of the forward and reverse currents. **You will have three data points: One for each weight force.**

QUESTIONS AND CALCULATIONS

1) **Find the distance d between the centers of the current carrying wires**. From figure 2 above, we see that, between the balance and touching positions, the mirror angle changes by $\varphi_{mirror} = \frac{a}{X_1}$ (*a* is the edge-to-edge distance between the wires) and the angle between the two reflected beams changes by $\varphi_{light} = \frac{y}{X_2}$. Since $\varphi_{light} = 2\varphi_{mirror}$, we can easily calculate the distance *a* from the measured quantities. When the wires touch, the center-to-center separation is d_0=0.003 m: This must be added to each of the computed distances. Therefore, the center-to-center distance should be calculated as

$$d = \frac{y\ X_1}{2X_2} + d_0 . \qquad (3)$$

2) The force applied is equal to the weight added in each trial plus the force exerted by the Earth's magnetic field. To cancel out the effect of the Earth's field, we need to compute the geometric mean of the forward and reverse currents: **The geometric mean is the square root of the product of the two currents**. By using this current, the only force in consideration is the weight force. At balance, this force is equal to the force the two wires exert on one another. **Compute the geometric means for each of your three trials.**

3) From the graph of forces versus current products and Eq. (2), find the value of the permeability of free space, μ_0. Compare your experimental result with the accepted value.

4) Do you think a current balance would make a good ammeter? Explain your answer. How does a simple machine such as this show the relationship between electrical and mechanical quantities?

5) Using your experimental value of μ_0, and the accepted value of the permittivity of free space, ε_0, compute the speed of light in a vacuum. How does this compare with the accepted value?

Last name: ……………………………… First name: ………………………………

DATA SHEETS

Step 3:

m_1 = ………………. m_2 = ……………….

Step 5, 6 and 7:

	I_F (Amps)	I_R (Amps)
m_1		
m_2		
$m_1 + m_2$		

Step 8, 9 and 10:

L = ………………. X_1 = ………………. X_2 = ……………….

y = ……………….