EXPERIMENT 12
THE CURRENT BALANCE

I. THEORY

In this experiment, we will determine the value of the permeability of free space. In order to do this we will be measuring the force between two parallel conductors that carry equal currents in opposite directions.

II. LABORATORY PROCEDURE

1. Gently remove the apparatus from the box.

2. Use the compass to align the arrow on the apparatus marked north with magnetic north.

3. Plug in the 9V transformer for the gallium heating and wire the circuit shown in Figure 10.

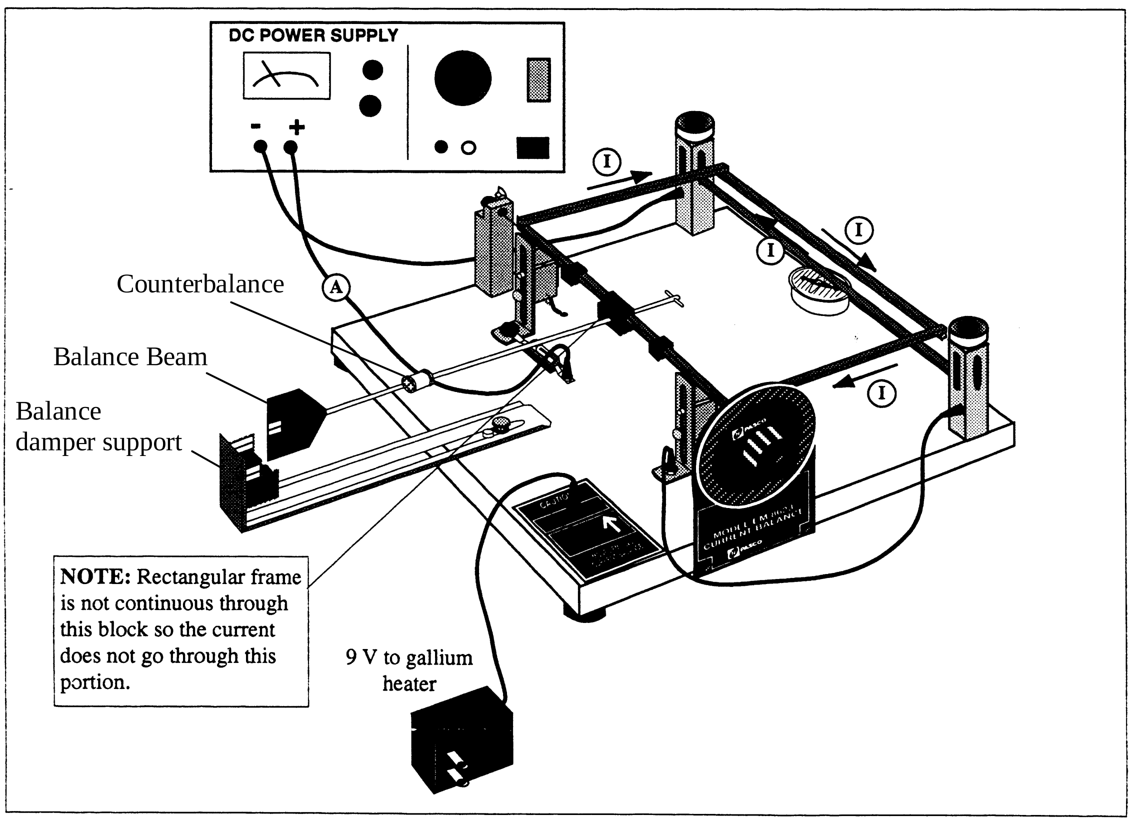

Figure 10 Wiring Diagram

4. Extend the balance damper support and the balance beam.

5. Slide the counterbalance until balance beam is horizontal and the rectangular loop is supported only by the torsion wire. If the rectangular loop touches the bottom conductor

you may have to lower the bottom conductor by turning the separation adjustment screws (Figure 11) on either side of the bottom conductor. You may find it difficult to get the rectangular loop horizontal by sliding the counterbalance. If so, fine adjustments can be made by turning the large degree dial. Turning this dial exerts a torque on the support wire. The reading on the degree dial is not needed in this experiment, but do not change it once you start taking data.

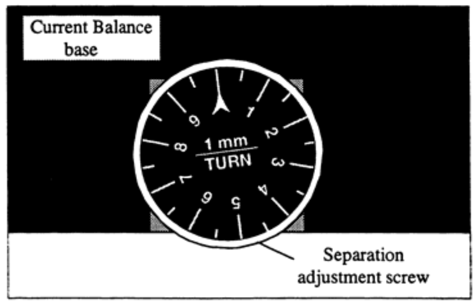

Figure 11 Top View of Separation Adjustment Screw

6. To complete the electrical circuit, open the gallium pots and raise the pots until the contacts are submerged in the gallium. If the gallium is still solid, you will need to wait until it melts to proceed. Lower the gallium pots until it appears that the gallium is no longer supporting the beam. The rectangular loop should again only be supported by the torsion wire. Check to see that the balance beam is still horizontal. If it is not, you will need to adjust the position of the counterbalance and/or turn the degree dial.

7. Position the slidable damping magnets (Figure 7) so that when the balance beam is horizontal (which it should now be) the index line on the vane lines up with both index marks on the magnetic damper (Figure 8).

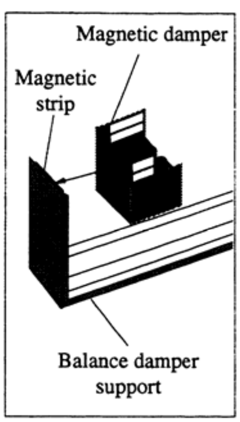

Figure 7

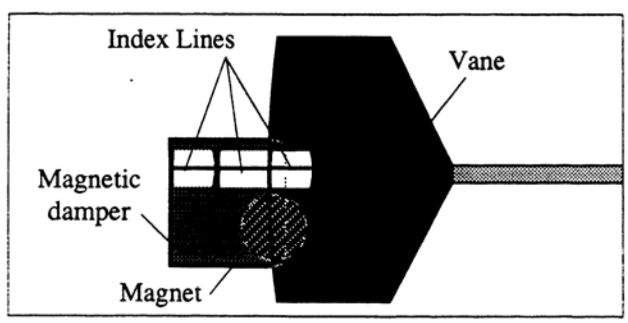

Figure 8

The rectangular loop is now in static equilibrium (even if the loop is not perfectly horizontal). The net force and net torque on the rectangular loop are both zero. In the lab, you will add two more forces to the loop; a gravitational force on the mass added to the mass pan and a magnetic force; these forces will need to be equal and opposite in order to make the loop horizontal again. You will know if the loop is horizontal, if the index line on the vane lines up with both index marks on the magnetic damper (Figure 8, again). This state of the balance may be referred to as the balance "reading zero."

8. You now need to make sure the two conductors opposite the balance beam are parallel. To do this place 200 mg in the mass pan. Rotate the two separation adjustment screws until there is no gap between the conductors on either end of the conductors.

9. Remove the 200 mg from the mass pan. Rotate the two separation adjustment screws counter clockwise alternately one turn at a time until the bottom conductor just barely touches the top conductor. The balance beam should still read zero. If it does not, lower the bottom conductor and return to step 5. (You may not have to make any adjustments, but check that the loop is balancing and that the conductors are still parallel.)

10. The separation of the centers of the two parallel conductors is now 3.2 mm, the diameter of each conductor. Lower the bottom conductor 8 mm. To do this, rotate the two separation adjustment screws clockwise alternately one turn at a time for a total of eight turns for each.

11. Have the instructor check your set up.

12. Rotate both the current and voltage knobs on power supply counterclockwise as far as they go. Plug in the power supply and turn it on. Rotate the voltage knob about ¼ of a turn clockwise.

13. Place 5 mg in the mass pan and adjust the current through the balance until the balance returns to zero. Record the mass and the current. (**Note:** You may need to increase the voltage if you are unable to increase the current enough to return the balance to zero. This however should not be required for 5 mg.)

14. Repeat Step 13 for 15 mg, 25 mg, 30 mg, 40 mg, and 50 mg. If you are unable to get a high enough current to balance 50 mg, try a smaller mass.

15. Rotate both the current and voltage knobs on power supply counterclockwise as far as they go. Turn off the power supply and unplug it. Also, unplug the 9V transformer. Disconnect all of the wires.

16. **Proceed with caution! The gallium pots may be hot.** Carefully lower the gallium pots to their original position and close them.

17. Return the balance beam and magnetic damper support to their original positions.

18. After returning all other equipment, except the power supply, to the box, check with your instructor about positioning the ***closed*** gallium pots to support the rectangular loop. Gently return the current balance to its box.

III. CALCULATIONS

1. Explain why the balance was aligned so that the two parallel conductors were in the magnetic north-south direction.

2. Calculate the center-to-center separation of the two parallel conductors.

3. Derive an expression for the force between the two parallel conductors in terms of their length, their separation, the current passing through them and the permeability of free space.

4. Make a table containing the quantities: Mass in Balance Pan, Current, and Current Squared.

5. Plot a graph of the mass in the balance pan versus current squared. Draw a straight line through the origin that best fits the plotted data points. Determine the slope of the line to three significant figures.

6. Derive an expression relating the slope of your graph to the length of the two conductors, the separation of the two conductors, the permeability of free space, and the acceleration due to gravity.

7. Calculate the permeability of free space from your expression above. Calculate the percent error in your experimental result. You will need the length of the two parallel conductors, 30.4 cm.