Magnetic Forces on Wires

EQUIPMENT

Qty	Description	Part #
1	Basic Current Balance	SF-8607
1	Current Balance Accessory	SF-8608
1	Ohaus Cent-o-Gram Balance	SE-8725
1	Low Voltage AC/DC Power Supply	SF-9584A
1	Large Base and Support Rod	ME-9355
1	Banana Plug Cord Set-Red (5 pack)	SE-9750
1	Banana Plug Cord Set-Black (5 pack)	SE-9751

INTRODUCTION

Magnets are mounted on an iron yoke and placed on a balance (resolution of at least 0.01g). One of the conducting paths is suspended between the magnets. The balance is used to measure the mass of the magnets and yoke prior to any current passing through the conducting path. Current is then passed through the conducting path, producing a force. The change in reading on the balance can be converted to find the magnetic force between the conductor and magnetic field.

Conductors of different length are included to measure the effect of length on magnetic force. Magnetic field can be varied by changing the number of magnets in the yoke. The power source is used to change the current supplied to the conductor. The Current Balance Accessory includes all the components needed to test the effect of angle on magnetic force.

THEORY

A current carrying wire in a magnetic field experiences a force that is usually referred to as a magnetic force. The magnitude and direction of this force depend on four variables: The magnitude and direction of the current (**I**); the strength of the magnetic field (**B**); the length of the wire (**L**); and the angle between the field and the wire (**θ**).

This magnetic force can be described mathematically by the vector cross product:

$$\mathbf{F_m = IL \times B}$$

Or in scalar form,

$$\mathbf{F_m = ILB\sin\theta}$$

Using the equipment included in the Magnetic Forces on Wires Experiment, all four variables (I, B, L, and θ) can be varied while measuring the resulting magnetic force.

SET UP

To set up the Current Balance:

1. Mount the Main Unit on a lab stand having with a rod 3/8 inch (1.1 cm) in diameter or smaller.
2. Select a Current Loop, and plug it into the ends of the arms of the Main Unit, with the foil extending down.
3. Place the Magnet Assembly on a balance with at least 0.01-gram sensitivity. Position the lab stand so the horizontal portion of the conductive foil on the Current Loop passes through the pole region of the magnets. The Current Loop shouldn't touch the magnets.
4. Connect the power supply and ammeter as shown above.

EXPERIMENT 1 - FORCE VS. CURRENT

1. Insert between 4 – 6 magnets into the magnet holder to provide a constant magnetic field. Enter the number of magnets used above Table 1.
2. Choose one of the current loops to use throughout the experiment and record the length of the current loop above Table 1.
3. Setup the current balance as shown above.
4. Determine the mass of the magnet holder and magnets with no current flowing. Record this value in the column under "Mass" in Table 1 below.
5. Turn on the power supply and set the current to 0.5 A. Determine the new "Mass" of the magnet assembly. Record this value under "Mass" in Table 1 below.
6. Increase the current in 0.5 A increments to a maximum of 5.0 A, each time measuring the new "mass" of the magnet assembly and recording this value in Table 1 below.

ANALYSIS

of Magnets Used: ________
Current Loop Used: ________

TABLE 1

Current (A)	"Mass" (grams)

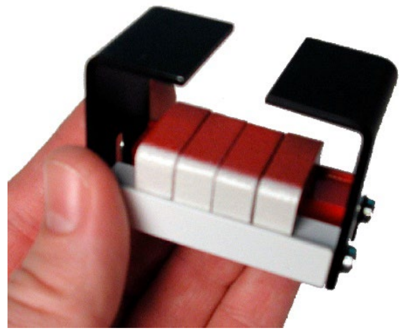
1. Subtract the "Mass" value for each of the currents from the "Mass" value for zero current to get the "Force" for each current.
2. Open the DataStudio file, Force_Current.ds
3. Enter the Current values used into the Force vs. Current table.
4. Enter the "Force" values into the Force vs. Current table.
5. Observe the shape of the Force vs. Current graph.

QUESTIONS

1. What relationship exists between the magnetic force and current through the conductor?
2. What is the physical meaning of the slope of the Force vs. Current graph?
3. What is the physical meaning of the vertical intercept of the Force vs. Current graph?
4. Can the vertical intercept be attributed to measurement error? Explain.
5. Write a proportionality expression that represents the relationship between Magnetic Force and Current.

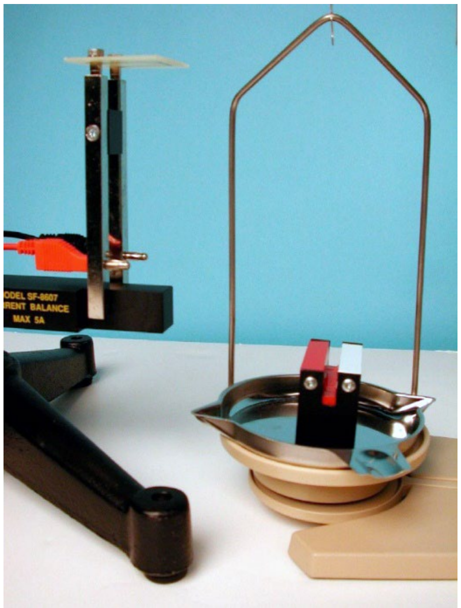
EXPERIMENT 2 - FORCE VS. LENGTH OF WIRE

1. Insert between 4 – 6 magnets into the magnet holder to provide a constant magnetic field. Be sure to center the magnets in the holder.



2. Enter the number of magnets used above Table 2.
3. Choose the shortest current loop to begin the experiment.

4. Setup the current balance as shown above.
5. Determine the mass of the magnet holder and magnets with no current flowing. Record this value above Table 2 below.
6. Turn on the power supply and set the current between 2.0 and 3.0 Amps. Record this value above Table 2.
7. Determine the new "Mass" of the magnet assembly. Record this value under "Mass" in Table 2 below.
8. Swing the arm of the main unit up, to raise the present current loop out of the magnetic field gap.



9. Pull the current loop gently from the arms of the base unit. Replace it with the next current loop and carefully lower the arm to reposition the current loop in the magnetic field.
10. Repeat steps 6-8 for each of the current loops and enter the appropriate data in Table 2.

ANALYSIS

# of Magnets Used: ________
Current Used: ____________
"Mass" with I = 0: _________

TABLE 2

Length (cm)	"Mass" (grams)

1. Subtract the "Mass" value for each of the currents from the "Mass" value for zero current to get the "Force" for each length.
2. Open the DataStudio file, Force_ConductorLength.ds
3. Enter the Lengths used into the Force vs. Length table.

4. Enter the "Force" values into the Force vs. Length table.
5. Observe the shape of the Force vs. Length graph.

QUESTIONS

1. What relationship exists between the magnetic force and length of conductor in the magnetic field?
2. What is the physical meaning of the slope of the Force vs. Length graph?
3. What is the physical meaning of the vertical intercept of the Force vs. Length graph?
4. Can the vertical intercept be attributed to measurement error? Explain.
5. Write a proportionality expression that represents the relationship between Magnetic Force and Length.

EXPERIMENT 3 - FORCE VS. MAGNETIC FIELD

1. Insert one magnet into the magnet holder and center the magnet in the holder.
2. Choose one of the current loops to use throughout the experiment and record the length of the current loop above Table 3.
3. Setup the current balance as shown above.
4. Determine the mass of the magnet holder and magnets with no current flowing. Record this value in the “Mass” I = 0 column in Table 3.
5. Turn on the power supply and set the current between 2.0 and 3.0 Amps. Record this value above Table 3.
6. Determine the new “Mass” of the magnet assembly. Record this value under “Mass” I > 0 in Table 3 below.
7. Turn off the power supply to change the current to zero.
8. Swing the arm of the main unit up, to raise the current loop out of the magnetic field gap.
9. Place an additional magnet into the magnet holder aligning the like poles of the magnets.
10. Place the holder in the back on the balance pan with the North and South poles in the same orientation as the last measurement.
11. Lower the arm of the main unit and reposition the current loop inside the magnetic field gap. Be certain the current loop isn’t touching the magnet holder.
12. Determine the mass of the magnet holder and magnets with no current flowing. Record this value in the “Mass” I = 0 column in Table 3.
13. Turn the power supply on to provide current through the loop.
14. Measure the new “Mass” of the magnet assembly and record this value in the “Mass” I >0 column in Table 3.
15. Repeat steps 7-14 for 3, 4, 5 and 6 magnets.

ANALYSIS

Current Used: ____________
Current Loop Used: _______

TABLE 3

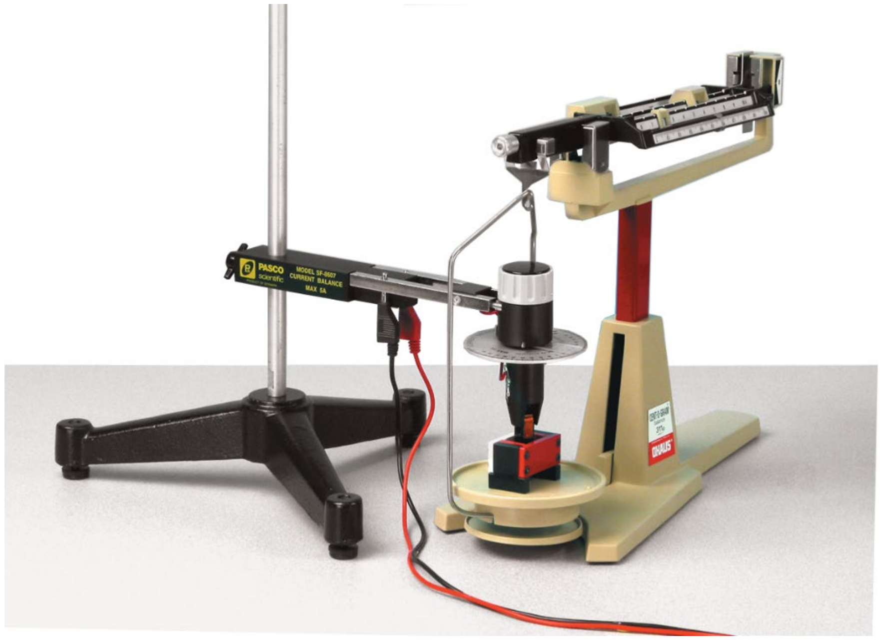
Magnetic Field (# of magnets)	"Mass" I = 0 (grams)	"Mass" I > 0 (grams)

1. Subtract the "Mass" value for each Magnetic Field from the "Mass" value for zero current to get the "Force" for each field strength.
2. Open the DataStudio file, Force_MagField.ds
3. Enter the Lengths used into the Force vs. Magnetic Field table.
4. Enter the "Force" values into the Force vs. Magnetic Field table.
5. Observe the shape of the Force vs. Magnetic Field graph.

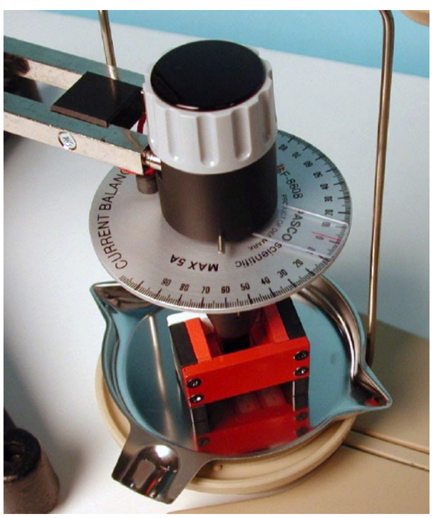
QUESTIONS

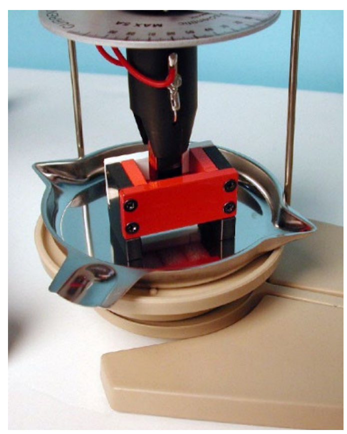
1. What relationship exists between the Magnetic Force and Magnetic Field?
2. What is the physical meaning of the slope of the Force vs. Magnetic Field graph?
3. What is the physical meaning of the vertical intercept of the Force vs. Magnetic Field graph?
4. Can the vertical intercept be attributed to measurement error? Explain.
5. Write a proportionality expression that represents the relationship between Magnetic Force and Magnetic Field.

EXPERIMENT 4 - FORCE VS. ANGLE



1. Place the smaller magnet holder from the Current Balance Accessory on the mass tray of the balance.
2. Attach the Current Balance Accessory to the arm of the current balance and lower the coil into the magnetic field of the magnet holder. The coil should not be touching the magnet holder.
3. Setup the current balance as shown above.
4. Set the angle to 0º such that the coils are facing the shorter dimension of the magnet holder (see photo below).





5. Determine the mass of the magnet holder and magnets with no current flowing. Record this value above Table 4.

6. Turn on the power supply and set the current between 2.0 and 3.0 Amps. Record this value above Table 4.
7. Determine the new "Mass" of the magnet assembly. Record this value under "Mass" I > 0 in Table 4 below.
8. Change the angle by 10º increments up to 90º, each time repeating steps 5 – 7. Record the measurements in Table 4.
9. Repeat steps 5 – 7 for angles between 0º and -90º and record the measurements in Table 4.

ANALYSIS

"Mass" with I = 0: ________
Current Used: ____________
Current Loop Used: _______

TABLE 4

Angle (degrees)	"Mass" I > 0 (grams)	Force (grams)
0		
10		
20		
30		
40		
50		
60		
70		
80		
90		
-10		
-20		
-30		
-40		
-50		
-60		
-70		
-80		
-90		

1. Subtract the "Mass" value for each Magnetic Field from the "Mass" value for zero current to get the "Force" for each angle.
2. Open the DataStudio file, Force_Angle.ds

3. Enter the Angles used into the Force vs. Angle table.
4. Enter the "Force" values into the Force vs. Angle table.
5. Observe the shape of the Force vs. Angle graph.
6. Print a copy of the Force vs. Angle graph.

QUESTIONS

1. Describe the relationship between Magnetic Force and Angle.
2. Which trigonometric function best fits the data? Explain your choice.
3. Draw this fit on the printout of the graph and write the proportionality expression between Magnetic Force and Angle.

FINAL ANALYSIS

1. Combine the proportionality expressions for all four experiments into one expression. Force should be on the left side of the expression and the other variables on the right side of the expression.
2. Write a few sentences explaining the relationship between Magnetic Force, Length, Current, Magnetic Field and Angle.
3. How would you convert this expression into an equation?
4. What is the constant of proportionality for this equation? Explain.
5. How could such an equation be used?