<u>Magnetic Force and Current Balance</u>

Based on the University of Scranton Lab by Kate Osenbach

<u>Magnetic Forces</u>

So far in this course we have only worked with electric fields. This lab involves magnetic fields, which are caused by moving charges (also known as electric current). When a charge is moving with velocity, **v,** through a magnetic field, the moving charge feels a magnetic force. In this lab, you will be using permanent magnets to create a magnetic field, and observing how current carrying wires feel forces due to the magnetic field. Magnets produce a magnetic field with two poles, a South pole and a North Pole. The magnetic field lines for the North pole always point <u>away</u> from the magnet (like how electric field lines always point away from positive charges). Therefore, the field lines always point towards the South pole. The equation for calculating magnetic force on a current carrying wire is:

$$\textbf{(1)} \qquad \mathbf{F_m} = \mathbf{IL} \times \mathbf{B} = \mathbf{ILB}\sin\boldsymbol{\theta}$$

where

$\mathbf{F_m}$ ≡ "magnetic force"
I ≡ "current"
L ≡ "length of wire"
B ≡ "magnetic field strength"
$\boldsymbol{\theta}$ ≡ "angle between magnetic field and current"

Equation **(1)** uses the *cross-product*, which means you must use the *right hand rule* to determine the direction of the magnetic force. This will be discussed in lab lecture.

This experiment involves placing your magnets on a scale while running a current carrying wire between them. Since the magnetic field of the magnets will exert a force on the charges in the wire (and the wire is held stationary), the magnet should feel a reaction force due to Newton's third law. This reaction force will cause the scale to read either a smaller or bigger mass for the magnet, depending on whether the force is attractive or repulsive. You will use this difference in mass to determine the magnetic force felt by the magnet using Newton's second law. The equation you will use is:

$$\textbf{(2)} \qquad \mathbf{F_m} = (\mathbf{m} - \mathbf{m_i})\mathbf{g}$$

where

$\mathbf{F_m}$ ≡ "force on magnets"
$\mathbf{m_i}$ ≡ "initial mass of magnets and holder"
m ≡ "mass of magnets with current turned on"

Procedure

1) Take the magnets at your station and make sure all six magnets are placed in the magnet holder. Have them aligned so that all North poles (red ends) are on one side of the "valley" and all South poles (white ends) are on the other. Place your magnets and holder on a "zeroed" electronic scale and record the initial mass of the magnets in Table 1.

2) Choose a "current plate" from the selection and measure the length of the wire that will run through the "valley" of the magnets. Record the length in Table 1. Attach the plate to the bendable joint, and make sure your power source wires are plugged into the prongs above the plate.

3) Bend the joint downwards until the wire on the current plate is running through the valley of the magnets. Make sure it is not touching the magnets. Turn on the power source and turn the current knob to set the current value to those in Table 1. For each new current, record the new mass of the magnets on the scale, and record them in the appropriate column. Use equation **(2)** to calculate the magnetic force felt by the magnets.

4) Once you have the data from ten trials, open Data Studio and select "Enter Data." Enter your values for current in the x-column, and the magnetic forces in the y-column to create a Magnetic Force vs. Current graph. Perform a linear fit and print your graph.

5) Repeat procedures 1-4, except set current **I** = 3 Amps. This time set a different current plate with a different wire length in the holder for each trial. Measure the lengths of the wires and record them in Table 2. Your graph will be Magnetic Force vs. Length.

6) Repeat procedures 1-4, except set the current **I** = 3 Amps and select a single current plate to use. Start the first trial by using only one magnet in the magnet holder, and add another magnet each separate trial. Don't forget to change the initial mass of you magnets each time, and make sure the magnets are positioned the same way (North to South) on the scale each trial. Your graph will be Magnetic Force vs. Magnetic Field (number of magnets).

Table 1: Magnetic Force vs. Current

Length [m] =	Initial Mass [kg] =	Magnets = 6
Current [Amps]	Mass (current ON) [kg]	Magnetic Force [N]
0.5		
1		
1.5		
2		

Table 2: Magnetic Force vs. Length

Current [A] = 1	Initial Mass [kg] =	Magnets = 6
Length [m]	Mass (current ON) [kg]	Magnetic Force [N]

Table 3: Magnetic Force vs. Magnetic Field

Current [A] = 1		Length [m] =	
Magnets	Initial Mass [kg]	Mass (Current ON) [kg]	Magnetic Force [N]
1			
2			
3			
4			
5			
6			

<u>Questions</u>

1) Describe in words how you would use the right hand rule to find the direction of the magnetic force in equation

2) For your Force vs. Magnetic Field graph, why can we plot integers for your B field values instead of the actual B field value for the entire magnet?

3) Draw a free-body diagram of the magnet on the scale, then use Newton's first law to prove that the magnetic force you found ≡ $\mathbf{F_m} = (\mathbf{m} - \mathbf{m_i})\mathbf{g}$. Show all algebra.

4) When measuring the value of length for the wire you used, why wasn't it necessary to measure the vertical wire lengths as well as the horizontal? (Hint: describe what effect each vertical piece of wire had on the magnet in terms of magnetic force)

5) Based on equation **(1)**, sketch the graph of Magnetic Force vs. Angle if the current, length, and magnetic field were kept constant, but only angle changed.