**Magnetic Force on Current**

## Objective

Test the theory of magnetic force on moving charges by examining the force exerted by a permanent magnet on a current immersed in the magnetic field.

## Equipment

- Rod and clamp
- Magnetic Assembly Box
- Triple Beam Balance
- Power Supply

## Theory

A charge moving through a magnetic field will experience a force of the form:

$$\vec{\mathbf{F}} = q\,\vec{\mathbf{v}} \times \vec{\mathbf{B}} \tag{1}$$

If we consider a current carrying wire of length $s$ placed in a magnetic field, we can consider a small section of this wire as $\Delta\vec{\mathbf{s}}$. If a total amount of charge $\Delta q$ passes through this wire segment in a time of $\Delta t$, then we can say that:

$$\Delta q\,\vec{\mathbf{v}} = \Delta q\,\frac{\Delta\vec{\mathbf{s}}}{\Delta t} \tag{2}$$

This can be written as:

$$\Delta q, \vec{\mathbf{v}} = \frac{\Delta q}{\Delta t}\Delta\vec{\mathbf{s}} = I\Delta\vec{\mathbf{s}} \tag{3}$$

Which means the force on that piece of wire is:

$$\Delta\vec{\mathbf{F}} = I\Delta\vec{\mathbf{s}} \times \vec{\mathbf{B}} \tag{4}$$

In the infinitessimal form

$$\mathrm{d}\vec{\mathbf{F}} = I\mathrm{d}\vec{\mathbf{s}} \times \vec{\mathbf{B}} \tag{5}$$

This can be integrated over the length of the conductor. If we assume that the conductor is a straight piece of wire then

$$\vec{\mathbf{F}} = \int \mathrm{d}\vec{\mathbf{F}} = \int I\mathrm{d}\vec{\mathbf{s}} \times \vec{\mathbf{B}} = I\vec{\mathbf{s}} \times \vec{\mathbf{B}} \tag{6}$$

Here $I$ is the current flowing through the conductor and $|\vec{\mathbf{s}}|$ is the length of the conductor.

## Procedure

By using a wire of length $s$ pointed perpendicular to the magnetic field of the magnet assembly and carrying current $I$, the total force would be:

$$F = mg + IsB = W + IsB \tag{7}$$

Where $m$ is the mass of the magnet assembly and the force due to that is the weight $W$.

Repeat the experiment below for two current loops, S-41 and S-42.

1. Place the magnet assembly on the triple beam balance and measure the weight equivalent mass $m_0$. Calculate the weight $W_0$
2. Fix the current loop in the clamp such that the bottom flat part is inside the magnet assembly but not touching. Make a note of the length of the conductor on the bottom part of the loop, $s$.
3. Run the power supply in current limited mode and apply current of $I_1 = 1A$, $I_2 = 2A$,$I_3 = 3A$, and $I_4 = 4A$.
4. For each current, balance the triple beam balance and read the weight in forms of balance reading, $m_i$ and calculate $W_i$.
5. Plot $W_1$ through $W_4$ on the $y$-axis and $sI_1$ through $sI_4$ on the $x$-axis.
6. The slope of the curve will be $B$ and the $y$-intercept should be $W_0$.

Use the following table to record the values of your measurements:

| $I$ (set) | $mz$ (measure) | $W$ (calc) | $s$ (set) | $sI$ (calc) |
|---|---|---|---|---|
| | | | | |

## Analysis

- Is the curve linear, hence confirming the theory?
- Compare the value of the $y$-intercept deduced form the fitted curve to the $W_0$ that you calculated from the mass of the magnet assembly.
- Calculate the value of $B$ for each current loop.
- Compare the value of $B$ obtained with two different current loops.