Keywords:
Lorentz force、Ampers’ right hand rule

Objective:
Denmark scientist Hans Christian Oersted accidentally found that the current-carrying wire would affect the pointing direction of the compass. Furthermore, due to the effort of Jean-Baptiste Biot、Felix Savart、Andre-Marie Ampere and Michael Faraday, revealed the secret relationship between the electricity and magnetism, and then established the foundation of the current electrical engineering. By means of analyzing between the relationship of the force on the current-carrying wire in the magnetic field between wire length、strength of the magnetic field and magnitude of current and the relationship of the angle between the wire and the magnetic field, so that you can experience their experience and then verify the secret of the electricity and magnetism.

Apparatus:
One Main Unit, six Current Loop PC Boards, magnet assembly(one with six magnets, one with three magnets)(Fig. 1), a Current Balance Accessory Unit (Fig. 2), a current balance, a power supply, a multimeter, several wires, one base and support rod, one Tesla Meter
Figure 1  Magnet Assembly

Figure 2  Current Balance Accessory Unit
**Principle**: Based on the investigation of Lorentz, the force on the current-carrying wire in the magnetic field is 
\[
\vec{F} = iL \times \vec{B} \quad \text{or} \quad F = iLB \sin \theta
\]
Thus, based on the preceding equation, the magnitude and the direction of the force depends on four variables:
(1) the magnitude of the current \( i \), (2) the length of the wire \( L \), (3) the strength of the magnetic field \( B \), (4) the angle \( \theta \) between the wire and the magnetic field.
You can vary the variables in the equation and measure the resulting magnetic force. Thus, we can verify Lorentz’s force equation.

**Instructions**: (1) The relationship between the force on the wire and the magnitude of the current \( i \)

1. Set up the apparatus as shown in Figure 4. Plug the sixth Current Loop PC Board into the ends of the arms of the Main Unit, with the foil extending down. Let the horizontal portion of the conductive foil on the current Loop pass through the pole region of the magnets. The Current Loop shouldn’t
touch the magnets. and then make the indicator of the power supply on zero position. (Make sure the direction of north pole and south pole of the little magnets should be the same when you put the little magnets on the magnet assembly.)

2. Determine the mass of the magnets with no current flowing. Record this value as M₁.

3. Set the current to 0.3A. Determine the new ‘mass‘ of the Magnet Assembly. Record this value as M₂.

4. Subtract the mass value with the current flowing from the value with no current flowing. Record this value as force.

5. Increase the current in 0.3A increments to a maximum of 2.0A, each time repeating steps 2-4. (i.e. 5 times in all) Plot a graph of force \( F \) versus current \( i \).

(2) The relationship between the force \( F \) on the current-carrying wire and wire length \( L \).

1. Set up the apparatus as in Figure 4. Vary the wire length by using one of the six different Current Loops. Determine the new “mass” of the Magnet Assembly.

2. Plot the graph of force \( F \) versus the length of the wire \( L \).
   (The length of the wire is at the remark.)
   (The wire length is at the remark.)

(3) The relationship between the force \( F \) versus the strength of the magnetic field \( B \).

1. Use the Tesla Meter to measure the strength of the magnetic field \( B \). (The
operation instructions of the Tesla Meter is appendix of the textbook.)

2. Set up the apparatus as in Figure 4. Select the fourth current loop PC board and plug it into the ends of the arms of the Main Unit.

**Q1 : Why should we use the fourth current loop PC board? Is there anything special?**

3. Mount the single magnet in the Magnet Assembly.

4. With no current flowing, determine the mass of the Magnet Assembly. Record this value as \( M_1 \).

5. Set the current to 1.5A. Determine the new “mass” of the Magnet Assembly. Record this value as \( M_2 \).

6. Subtract the mass value with the current flowing from the value with no current flowing. Record this value as force.

7. Add additional magnets, one at a time. Each time you add a magnet, one at a time, repeat step 1-6. Plot the graph of force \( F \) versus the strength of the magnetic field \( B \).

(4) The relationship between the force \( F \) versus the angle \( \theta \).

1. Set up the apparatus as shown in Figure 5.

2. Determine the mass of the Magnet Assembly with no current flowing. Record this value as \( M_1 \).

3. Set the angle to 0° with the direction of the coil of wire approximately parallel to the magnetic field. Set the current to 1.0 A, and the force on the wire should be 0 at the same time. This is the standard.

4. Set the angle to 0°, 30°, 45°, 60° and 90°. Subtract the mass value with the current flowing from the value with no current flowing. Record this value as force.

5. Set the angle to 0°, -30°, -45°, -60° and -90°. Subtract the mass value with the current flowing from the value with no current flowing. Record this value as force.

6. Plot the graph of force \( F \) versus angle \( \theta \) and the graph of force \( F \) versus \( \sin \theta \).

**Questions :**

**Q2 : What does the red pole of the magnet represent? How can you determine?**

**Q3 : Is the magnitude of the magnetic proportional to the number of the magnets?**

**Q4 : In (3), if only mount 2 magnets on the Magnet Assembly, does the position of the magnets affect the result?**

**Q5 : How could we derive \( \vec{F} = i \vec{L} \times \vec{B} \) from original Lorentz’s force eq.**
\[ \vec{F} = q \vec{v} \times \vec{B} \]

Q6: Does the force in \( \vec{F} = q \vec{v} \times \vec{B} \) do work?

Q7: What is the application of Lorentz force?

Connect to the power supply.

- Figure 5

Notice:
1. The probe of the Tesla Meter is easily broken and is very expensive. Please be careful to use it. If it is broken, you should pay for it.
2. The maximum load of the Current Loop PC Board is 2A, the maximum load of the Current Balance Accessory Unit is 5A, and the maximum load of the power supply is 3A. Please avoid the current over the maximum load of the instrument, so that the instrument isn’t broken.

Remark:

<table>
<thead>
<tr>
<th></th>
<th>1st Current Loop PC Board</th>
<th>2nd Current Loop PC Board</th>
<th>3rd Current Loop PC Board</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length</td>
<td>2.2 cm</td>
<td>4.2 cm</td>
<td>3.2 cm</td>
</tr>
<tr>
<td></td>
<td>4th Current Loop PC Board</td>
<td>5th Current Loop PC Board</td>
<td>6th Current Loop PC Board</td>
</tr>
<tr>
<td>Length</td>
<td>1.2 cm</td>
<td>6.4 cm</td>
<td>8.4 cm</td>
</tr>
</tbody>
</table>
I. Power: **Before use, you should install the probe**, and then you can press the POWER switch (1).

II. Units of measurement selection: Rotate the function selector to the UNITS position (4). Press the SELECT (2) pushbutton to select the unit you need. In this experiment, the unit needed is “T”.

III. Range selection: Rotate the function selector to the RANGE position (4). Press the SELECT (2) pushbutton to select “AUTO RANGE”.

IV. Zero function: After rotating the function selector to the ZERO position (4), insert the probe into the ZERO FLUX CHAMBER, and then press RESET (3) to begin zeroing process.

V. Measurement of the magnetic field: After zeroing process, rotate the function selector to the MEASURE position (4), and then insert the probe into the magnetic field which we want to measure. The Tesla Meter can only measure the magnetic
filed which is perpendicular to the surface of the probe, and the sensor is mounted in the peak of the probe. Therefore, you should pay attention to the position of the probe. The principle of is in Unit Eight “Hall Effect”.

(Notice:The probe is easily broken. Be careful to use it.)