Unit-18　Magnetic Force on Wire Experiment

Objective：

By analyzing the relationship between the force on a current-carrying wire in a magnetic field and four variables - wire length, strength of the magnetic field, magnitude of current as well as the angle between the wire and the magnetic field, we can verify the wonders between electricity and magnetism.

Apparatus：

Magnetic force apparatus (current balance accessory unit, current loop PC noard, horseshoe magnets, magnet assembly), power supply, Tesla meter, electronic scales

Principle：

Based on the investigation of Lorentz's, the force on a current-carrying wire in a magnetic field is

$$\vec{F} = i\vec{L} \times \vec{B}$$

or

$$F = iLB\sin\theta$$

Thus, from the preceding equation, the magnitude and the direction of the force depend on the following 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 θ between the wire and the magnetic field.

You can change those variables in the equation and measure the resulting magnetic force to verify Lorentz's force equation.

A.　Instruction Manual of the Tesla Meter

(a)　Prepare for before operating

1. Plug the probe into the Tesla Meter.
2. You should connect to Mode: PSU-5 transformer before you press ON/OFF buttom.
3. Prepare the zero flux chamber.

4. Press ON/OFF buttom. After turning on, the monitor will show “CAL6~CAL0” (now, the Tesla meter is conducting self-adjustment.)

(b) Selection of measurement units

1. Press SHIFT, then press ← (choose UNITS) and use ↑/↓ to select the unit you need. The unit needed in this experiment is “T” (or mT).
2. After choosing the unit, press SHIFT and use ← to confirm it.

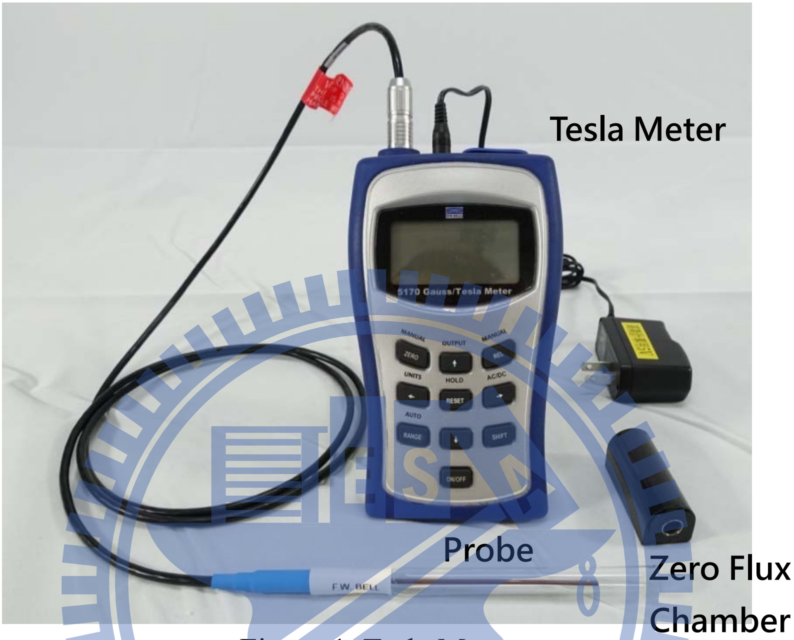

Figure 1. Tesla Meter

(c) Range selection

1. If the monitor shows up “AUTO RANGE”, the Tesla meter is set on automatic postion function.
2. If there is no “AUTO RANGE”, press SHIFT and choose RANGE to select the function.

(d) Zeroing

1. Insert the probe into the zero flux chamber.
2. And press ZERO to zero it. If you hear the voice “bi bi” from machine, the zeroing process has been completed.

(e) Polarity measurement of the magnet

1. Put the probe into a magnetic field, if the value of the magnetic field is positive then the magnet surface faces to F.W BELL is the polarity of “N”. If the value is negative, it’s “S”.

Remarks：

1. Be careful with the probe of Tesla Meter, which is fragile and very expensive.
2. If the probe isn't used, be sure to put on the protective sleeve in case of damage.
3. While plugging in the probe, make sure the direction of the connector's pins so as to prevent fracturing.
4. Before turning on the power of Tesla Meter, plug in the sensor probe first. After measurement, turn off the power first and then unplug the probe.
5. Before using Tesla Meter, check the manual to learn how to reset it to zero.
6. Never weigh any object that will exceed the capacity of electronic scale, which is about 600.00 grams.
7. The maximum load of the Current Loop PC Board is 2.00 A, the maximum load of the Current Balance Accessory Unit is 5.00 A.
8. Don't mistake Tesla Meter power transformer for electronic scale power transformer.

Procedure：

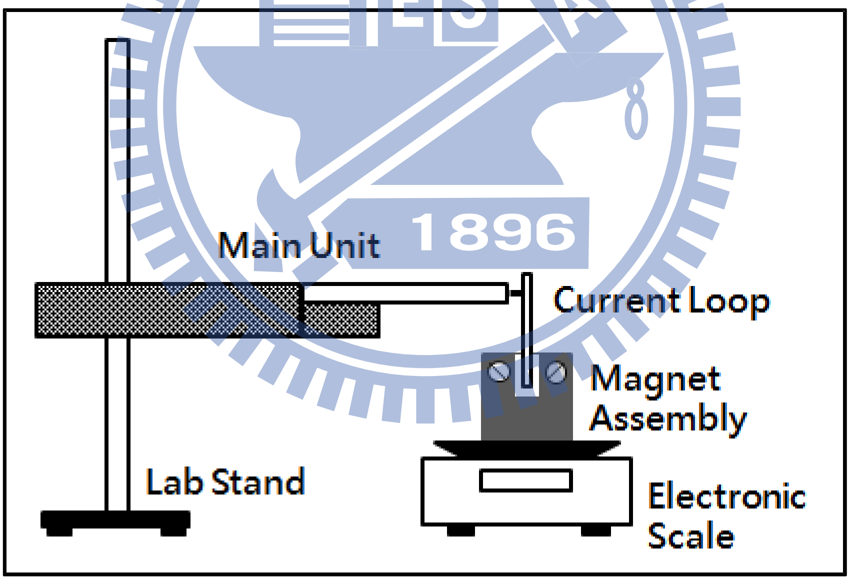

Figure 2. Experiment set-up I

A. The relationship between the force *F* and the magnitude of the current *i*

1. Set up the apparatus as shown in figure 2.
2. Put six horseshoe magnets on the magnet assembly. Make sure the direction of North and South poles of the magnets are the same.
3. Measure and record the strength of the magnetic field B in the indentation of the magnet assembly with the Tesla Meter.
4. Insert the No.6 Current Loop PC Board (L = 8.40 cm) into the end of the Main Unit.

5. Put the magnet assembly on an electronic scale and place the Current Loop PC Board between the two poles of magnets. Mark the weight of the magnet assembly while no current flowing as W_1.
6. Set the current to 0.50 A, and it determine the new "weight" of the magnet assembly. Mark this value as W_2
7. The difference of W_1 and W_2 determine the force on the wire.
8. Vary current and repeat above steps.
9. Plot $F-i$ diagram.

B. The relationship between the force *F* and wire length *L*

1. Set up the apparatus as shown in figure 2.
2. Put six horseshoe magnets on the magnet assembly. Make sure the direction of North and South poles of the magnets are the same.
3. Measure and record the strength of the magnetic field B in the indentation of the magnet assembly with the Tesla Meter.
4. Insert the No.6 Current Loop PC Board (L = 8.40 cm) into the end of the Main Unit.
5. Put the magnet assembly on an electronic scale and place the Current Loop PC Board between the two poles of magnets. Mark the weight of the magnet assembly while no current flowing as W_1.
6. Set the current to 1.50 A, and it determine the new "weight" of the magnet assembly. Mark this value as W_2.
7. The difference of W_1 and W_2 determine the force on the wire.
8. Vary the wire length by using different current loop PC board (Table.1) and repeat above steps
9. Plot $F-L$ diagram.

Table 1. Current Loop PC Board

Number # NO.	1	2	3	4	5	6
Length L (cm)	2.20	4.20	3.20	1.20	6.40	8.40

C. The relationship between the force *F* versus the strength of the magnetic field *B*

1. Set up the apparatus as shown in figure 2.
2. Put six horseshoe magnets on the magnet assembly. Make sure the direction of North and South poles of the magnets are the same.
3. Measure and record the strength of the magnetic field B in the indentation of the magnet assembly with the Tesla Meter.
4. Insert the No.4 Current Loop PC Board (L = 1.20 cm) into the end of the Main Unit.

5. Put the magnet assembly on an electronic scale and place the Current Loop PC Board between the two poles of magnets. Mark the weight of the magnet assembly while no current flowing as W_1.
6. Set the current to 1.50 A, and it determine the new "weight" of the magnet assembly. Mark this value as W_2.
7. Change the number of magnets to vary the strength of the magnetic field. Repeat the above steps and make sure the direction of North and South poles of the magnets are the same.
8. The difference of W_1 and W_2 determine the force on wire.
9. Plot $F-B$ diagram.

D. The relationship between the force *F* versus the angle θ

1. Set up the apparatus as shown in figure 3.

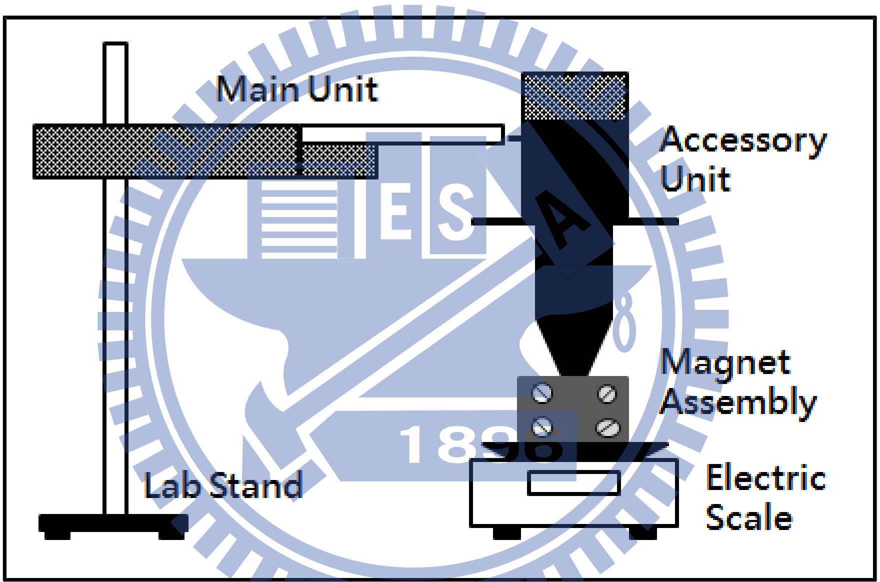

Figure 3. Experiment set-up II

2. Measure and record the strength of the magnetic field B in the indentation of the square-shaped magnet assembly with a Tesla Meter.
3. Insert the current balance accessory unit into the end of the main unit and set the angle to 0.0°.
4. Put square-shaped magnet assembly on an electronic scale. Mark the weight of the square-shaped magnet assembly while no current flowing as W_1.
5. Set the current to 1.50 A. Change the direction of the square-shaped magnet assembly until its weight is the same as W_1.
   [Note] Then, the direction of the wire coil approximately parallel to the magnetic field, and the force on the wire should be zero at the same time.
6. If the force is not zero, you can adjust the angle until the force becomes zero. Or now the value of angle φ is a calibration.

7. Vary the angle with the value -90°, -60°, -45°, -30°, -20°, -10°, 0°, 10°, 20°, 30°, 45°, 60° and 90°. Determine the new "weight" of the square-shaped magnet assembly. Mark this value as W_2.
8. The difference of W_1 and W_2 determine the force on wire.
9. Plot $F - sin\theta$ diagram.

<u>Questions</u>：

1. Please explain the difference reading between the Gaussian meter probe in the vertical or horizontal direction.
2. No current flowing. The magnet assembly weight are different when the wire inside or outside the magnet assembly. Please explain.
3. A current carrying straight conductor has magnetic field. Will this magnetic field affect the experiment? Please explain.
4. In the experiment of the relationship between the force F versus the strength of the magnetic field B, why do we need to use the No.4 current loop PC boards? What is the purpose for using it? Please explain.