

## Experiment # 6

# MAGNETIC FORCE ON A CURRENT CARRYING CONDUCTOR

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### OBJECTIVE

To measure the force on a conductor carrying electric current placed in a magnetic field. The force is measured as the current and the length of the conductor are varied. The effect of the magnetic field strength on the resulting force is also studied.

### EQUIPMENT REQUIRED

1. Balance.
2. Wire loop,  $L=50\text{ mm}$ .
3. Wire loop,  $L=25\text{ mm}$ .
4. Wire loop,  $L=12.5\text{ mm}$ .
5. Power supply.
6. Ammeters (two).
7. 900-turn coils (two).
8. Pole pieces (two).
9. Iron core,  $U$ -shape.
10. Distributor.
11. Right angle clamp.
12. Bridge rectifier.
13. Teslameter with a tangential probe.
14. Multimeter.

### INTRODUCTION

Consider a straight conductor of length  $L$  and carrying current  $I$  placed in a region of a uniform magnetic field  $\mathbf{B}$ , where the magnetic field is perpendicular to the conductor. The magnetic force on the conductor is given by:

$$F = IBL \dots\dots\dots (1)$$

The direction of the force is given by:

$$a_F = a_I \times a_B \dots\dots\dots (2)$$

### PROCEDURE

The experimental set up is shown in Figure 1. The AC current out of the power supply is rectified (call it  $I_F$ ) and passed through the 900-turn coils to produce a constant magnetic field between the pole pieces. The DC current out of the power supply is passed through the conductor (call it  $I_L$ ).

#### PART A: Force vs. conductor current

1. Attach the 50 mm wire loop ( $N=1$ ) to the balance.
2. Set the AC output voltage of the power supply to the 12 V setting.
3. Adjust the balance to the horizontal position when the switch is off ( $I_F = 0$ ). Record the reading on the balance dial.

4. Turn the switch on and adjust  $I_L$  to 0.5 A. Readjust the balance again to the horizontal position. Record the reading of the balance dial.
5. The difference in the balance readings of steps (3) and (4) is the force in grams exerted on the wire. To obtain the force in mille-Newton ( $mN$ ), multiply the force in grams by 9.81.
6. Measure the magnetic field between the pole pieces using the Teslameter and the tangential probe. This value of the magnetic field will be used in the theoretical calculations. (*Remember to calibrate the Teslameter. After calibration, push the DC button and choose the 300mT setting*).
7. Repeat steps (3)-(6) for a range of conductor current between 0.5 and 5 A.

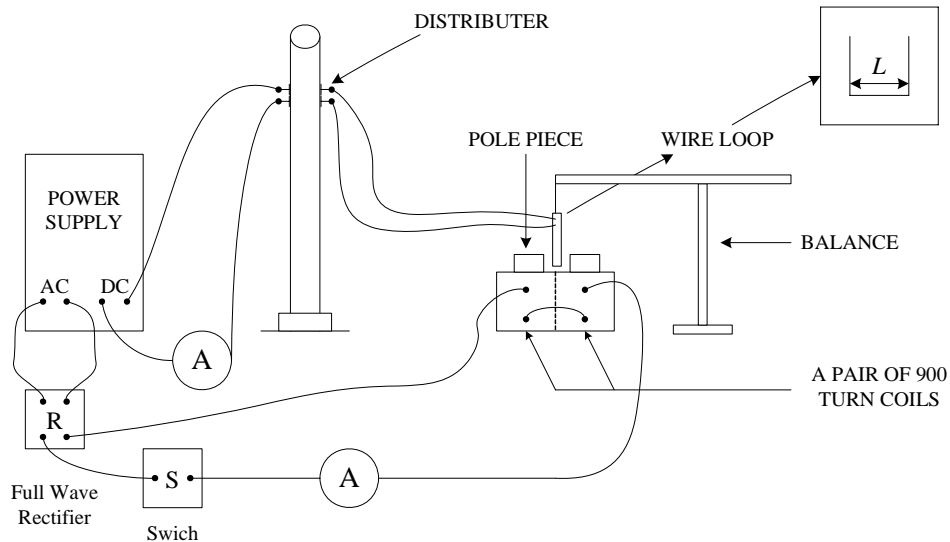


Figure 1: Experimental set-up

**Table 1: Force variation with Conductor Current**

$L = 50 \text{ mm}$ ,  $N = 1$ ,  $F_{\text{exp}} = |M - M_0| \times 9.81$ , where  $M$  (mass) in grams.,  $F_{\text{theo}} = I_L B L$

| $I_L$ (A) | $B_{\text{(experimental)}}$ (mT) | Balance Reading $M$ (gms) | $F_{\text{(experimental)}}$ (mN) | $F_{\text{(Theoretical)}}$ (mN) |
|-----------|----------------------------------|---------------------------|----------------------------------|---------------------------------|
| 0         | 0                                | $M_0 =$                   | 0                                | 0                               |
| 0.5       |                                  | $M =$                     |                                  |                                 |
| 1.0       |                                  | $M =$                     |                                  |                                 |
| 1.5       |                                  | $M =$                     |                                  |                                 |
| 2.0       |                                  | $M =$                     |                                  |                                 |
| 2.5       |                                  | $M =$                     |                                  |                                 |
| 3.0       |                                  | $M =$                     |                                  |                                 |
| 3.5       |                                  | $M =$                     |                                  |                                 |
| 4.0       |                                  | $M =$                     |                                  |                                 |
| 4.5       |                                  | $M =$                     |                                  |                                 |
| 5.0       |                                  | $M =$                     |                                  |                                 |

**PART B: Force vs. conductor length**

Repeat the steps of *PART A* for different conductor lengths ( $N=1$ ) with  $I_L = 5.0$  A only.

**Table 2: Force variation with Conductor Length**

$$I_L = 5 \text{ A}, N = 1, F_{\text{exp}} = |M - M_0| \times 9.81, \text{ where } M \text{ (mass) in grams.}, F_{\text{theo}} = I_L B L$$

| L (mm) | $B_{\text{exp}}$ (mT) | Initial Balance $M_0$ (gms) | Final Balance M (gms) | $F_{\text{(experimental)}}$ (mN) | $F_{\text{(Theoretical)}}$ (mN) |
|--------|-----------------------|-----------------------------|-----------------------|----------------------------------|---------------------------------|
| 12.5   |                       |                             |                       |                                  |                                 |
| 25     |                       |                             |                       |                                  |                                 |
| 50     |                       |                             |                       |                                  |                                 |

**PART C: Force vs. magnetic field**

1. Attach the 50 mm ( $N=1$ ) wire loop to the balance.
2. Fix  $I_L$  to 5 A.
3. Measure the force as the current  $I_F$  is varied. (This is done by choosing different voltage settings on the power supply).
4. Measure the corresponding magnetic field.

**Table 3: Force variation with Magnetic Field**

$$I_L = 5 \text{ A}, L = 50 \text{ mm}, N = 1, F_{\text{exp}} = |M - M_0| \times 9.81, \text{ where } M \text{ (gram)}, F_{\text{theo}} = I_L B L$$

| V (Volts) | $I_F$ | $B_{\text{exp}}$ (mT) | Balance Reading 'M' (gms) | $F_{\text{(experimental)}}$ (mN) | $F_{\text{(Theoretical)}}$ (mN) |
|-----------|-------|-----------------------|---------------------------|----------------------------------|---------------------------------|
| 0         | 0     | 0                     | $M_0 =$                   | 0                                | 0                               |
| 2         |       |                       | $M =$                     |                                  |                                 |
| 4         |       |                       | $M =$                     |                                  |                                 |
| 6         |       |                       | $M =$                     |                                  |                                 |
| 8         |       |                       | $M =$                     |                                  |                                 |
| 10        |       |                       | $M =$                     |                                  |                                 |
| 12        |       |                       | $M =$                     |                                  |                                 |
| 15        |       |                       | $M =$                     |                                  |                                 |

**QUESTIONS FOR DISCUSSION**

1. Plot the experimental and the theoretical relations between the force on the conductor and the conductor current, the conductor length and the magnetic field.
2. Why did we ignore the effect of the magnetic field of the surroundings?
3. Why did we ignore the effect of the vertical portions of the conductor loop?
4. Plot and explain the relation between the magnetic field and  $I_F$ . (Use the results of *PART C*).