EXPERIMENT EM3: LORENTZ FORCE AND TRANSFORMER

Related course: KIE2007 (Basic Electromagnetics)

OBJECTIVES:
Refer to each test

EQUIPMENT:
Power supply, rectifier, Cobra3 unit, current sensor, coil, iron core, multi-tap transformer

INSTRUCTIONS:

1. Record all your results and observations in a log book / on a piece of paper / pen drive
2. Follow the demonstrator's instructions throughout the experiment

REFERENCE(S):
Refer to the main references of KIE2007

TEST:
TEST 1: Current Balance / Force acting on a current-carrying conductor
TEST 2: Transformer

TEST 1: Current Balance / Force acting on a current-carrying conductor

OBJECTIVES:

1. To determine the direction of the force in dependence on the direction of the current and the direction of the magnetic field
2. To measure the force F as a function of the current I_L in the conductor loop with a constant magnetic induction B and for conductor loops of various sizes
3. To measure force F as a function of the coil current I_m for a conductor loop. The magnetic induction B is proportional to the coil current I_m with sufficient accuracy.

INTRODUCTION:

In electromagnetism, the Lorentz force is the combination of electric and magnetic force on a point charge due to electromagnetic fields. If a particle of charge q moves with velocity v in the presence of an electric field E and a magnetic field B, then it will experience a force

$$\boldsymbol{F} = q\boldsymbol{E} + q\boldsymbol{v} \times \boldsymbol{B}$$

The first term is contributed by the electric field. The second term is the magnetic force and has a direction perpendicular to both the velocity and the magnetic field. The magnetic force is proportional to q and to the magnitude of the vector cross product $\boldsymbol{v}$.

In this experiment, the force acting on a current carrying conductor loop in a uniform magnetic field (Lorentz Force) is measured with a force sensor. The uniform magnetic field is generated by an electromagnet. Conductor loops of various sizes are suspended between the pole piece of the electromagnet and the Lorentz Force is determined as a function of the current and magnetic induction. The magnetic induction can be varied with the coil current.

PROCEDURES:

1. Set up the equipment as shown in Figure 1 and Figure 2. Connect the coil and iron core in series with the rectifier and AC output of the power supply. Connect 6A current sensor to Analog In 2/S2 of the Cobra3 unit. Connect a switch between 6A current sensor and rectifier.
2. Suspend the conductor loops on the force/Newton sensor and connect it with two light flexible metal strips to the distributor and over the other 6A current sensor to the DC voltage output of the power supply. Connect this 6A current sensor to Analog In 1/S1 of the Cobra3 unit. The distance between the metal strips should be as large as possible and they should only sag slightly. The attractive force between them is not negligible for high currents.
3. Connect the Cobra3 unit to the computer USB port.
4. Start the **Measure** program. Select **Gauge** > **PowerGraph** and on the **Setup** chart, click the Newton sensor symbol. Set the range to ± 0.4 N, the unit to mN, turn the display on and the averaging off. Before recording any measurement, click the **Tara** button there.
5. On the **Settings** chart of **PowerGraph**, select **Time** as x-data set and select all the channels there to be recorded. Start and stop conditions are to be **Key press** and data recording **Automatically** with 30 ms. On the **Displays** chart, install displays for all channels to be recorded by double-clicking **<new display>**. Add a diagram to record the force and current **I1**. **Auto range** is favourable for the diagram for both channel and x-bounds.

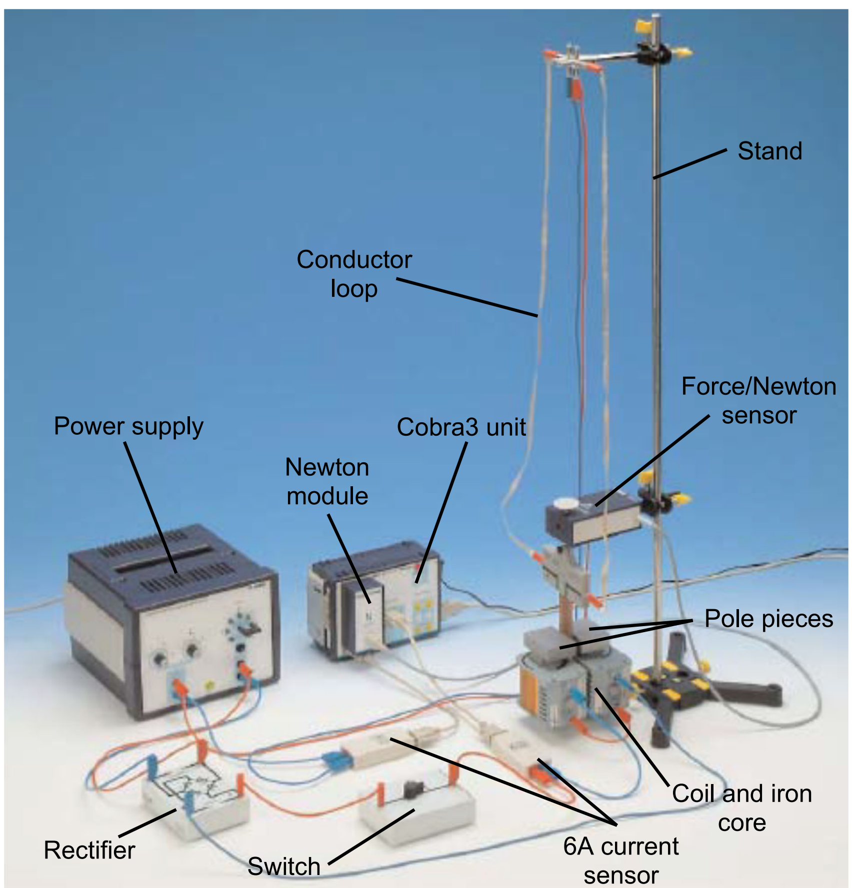

Figure 1: Equipment setup for Lorentz Force experiment

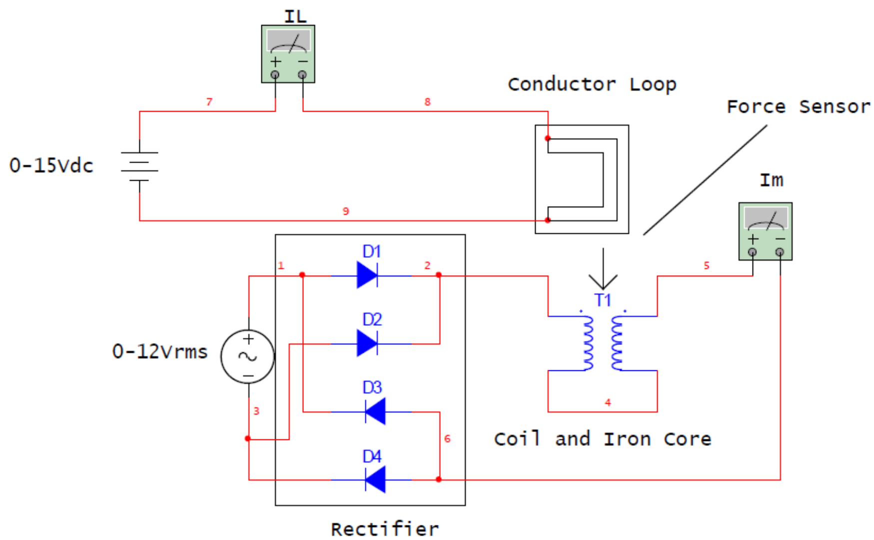

Figure 2: Rectifier connection diagram

Part 1

1. Select a fixed voltage of 12V AC for the coil and measure the current I_m in the coil.
2. Place the pole pieces on the coil and iron core with an air gap of about 4 cm. Suspend the conductor loop with *l* = 25 mm from the force sensor with its horizontal section perpendicular to the lines of the magnetic field.
3. Click the **Tara** button. Set conductor current of I_L = 5A. Start the measurement with **Continue** button but now no data recording is needed.
4. Observe the direction and amount of the force on the displays of the computer while altering the direction of the current and the angle between conductor and field (by changing the polarity and by rotating the magnet).
5. Without a magnetic field, observe the force displayed with and without current flowing through the conductor loop. Record all observations.

Part 2

1. Select a fixed voltage of 12V AC for the coil and measure the current I_m in the coil.
2. Place the pole pieces on the coil and iron core with their edges parallel and with an air gap of 1cm and hang the conductor loop with *l* =12.5 mm and *n*=1 on the force sensor.
3. Click the **Tara** button (after clicking the **Newton module** symbol). Run the horizontal section of the conductor perpendicular to the field lines and in the middle of the uniform field.
4. Now start data recording with the **Start measurement** button and increase the current in the conductor I_L (**Analog in 2 / S2 – I2**) in steps of 1 A with the control on the power unit up to 5 A.
5. For every step of I_L, switch the current I_m (**Analog In 1 /S1 – I1**) of the two coils on and off with the switch (maybe several times). This is to allow you to evaluate the change of the force easily by seeing only the effect of the magnetic field without paying attention to an offset because of sensor drift or a bad Tara (due to forces on the conductor strips).
6. Stop data recording. Repeat the procedure with the other conductor loops:
   a) *l* = 25mm and *n* = 1

b) l = 50mm and n = 1
c) l = 50mm and n = 2

7. Use the **Survey** function of the **measure** program to evaluate the obtained curves. Read out the force differences and the current values I_L (**I1**).
8. Plot the force vs. current I_L for all four conductor loops using **Measurement** > **Enter data manually….**
9. Several curves may be brought into one diagram with **Measurement** > **Assume channel….**
10. Use the **Scale curves** feature **set to values** for scaling the curves in one diagram. Save the diagram.
11. Use the **Regression** function to evaluate the slopes of the curves. Plot the slope of the force vs. conductor length in the field.

Part 3

1. With the conductor loop l = 50 mm, n = 2, record measurement by keeping the current I_L of the loop constant at 5A but by varying the current through the magnet coils I_m by setting different voltages on the power supply (0-12Vrms).
2. Record the data in the same way as in Part 2. Plot the force vs. the current through the field generating coil I_m. Comment on the relation between them.

TEST 2: Transformer

OBJECTIVES:
To measure the primary and secondary voltage of a transformer

PROCEDURES:

1. Connect the experimental set-up as shown in Figure 3. This connection is open circuit test of a transformer.
2. Fix the turn ratio n to one position. Vary the voltage supply from 0 to 15V rms in step of 2V and record the primary voltage U_P and secondary voltage U_S. Plot U_S vs. U_P.
3. Use the transformer as a step-up transformer. Fix the primary voltage U_P to 15Vrms and record the secondary voltage U_S for different turns ratio n. Plot U_S vs. n.
4. Use the transformer as a step-down transformer. Fix the primary voltage, U_P to 15Vrms and record the secondary voltage U_S for different turns ratio n. Plot U_S vs. n.

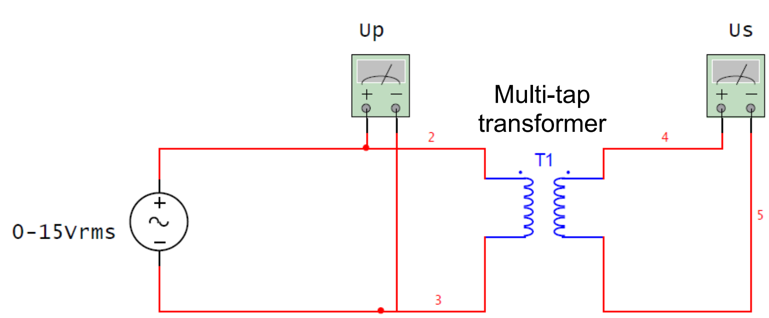

Figure 3: Experimental setup for transformer

END OF EXPERIMENT