EXPERIMENT 10

Magnetic Induction

Purpose:

- To investigate the relationship between the induction voltage and the strength of the magnetic field by changing the current in the field coil
- To investigate the relationship between the induction voltage and the applied AC frequency
- To investigate the relationship between the induction voltage and the number of turns of induction coils
- To investigate the relationship between the induction voltage and the diameter of induction coils

Experimental Instruments:

- Field coil, 750 mm, 485 turns/m
- Induction coils, consisting of,

  300 turns, dia. 41 mm

  300 turns, dia. 33 mm

  300 turns, dia. 26 mm

  200 turns, dia. 41 mm

  100 turns, dia. 41 mm
- Function generator
- Digital counter
- 2 avometer

Theoretical Information:

An electromotive force (emf) can be induced in a circuit by a changing magnetic field. This phenomenon can be simply observed when you move a magnet toward to or away from a loop of wire. If you connect an ammeter to the circuit, you would notice that current is induced as you move the magnet. This observation can be explained by the **Faraday's law of induction**, which is defined by,

$$\varepsilon = -\frac{d\Phi_B}{dt} \qquad (10.1)$$

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In Equation (10.1), Φ_B represents the magnetic flux given as,

$$\Phi_B = \int \vec{B}.d\vec{a} \tag{10.2}$$

If the single loop is replaced by a coil consisting of N turns, the total induced emf in the coil becomes,

$$\varepsilon = -N\frac{d\Phi_B}{dt} \tag{10.3}$$

$$\varepsilon = -N\frac{d}{dt}(B.A.\cos\theta) \tag{10.4}$$

The negative sign in the Equations (10.1)-(10.4) can be explained by the Lenz's law. Lenz's law states that the polarity of the induced emf is such that it tends to produce a current that creates a magnetic flux to oppose the change in magnetic flux.

The induced emf value can be changed by the magnitude of B, the area enclosed by the loop (A) or the angle θ between B and the normal to the loop.

As you remember from Experiment 8, the magnetic field of a long coil is very approximately defined as,

$$B = \mu_0 I\frac{N}{L} \tag{10.5}$$

as long as the length of the coil is much larger than the diameter of the coil.

If the current flowing through the field coil is alternating current defined by,

$$I(t) = I_0 \sin\omega t \tag{10.6}$$

then the magnetic field strength in the field coil alternates in phase as,

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$$B(t) = \mu_0 \frac{N}{L} I_0 \sin \omega \mathrm{t} \qquad (10.7)$$

Now suppose that an induction coil, which has N' number of turns and A' cross-sectional area, is placed in the middle of the field coil. Then the induced voltage by the induction coil is,

$$\varepsilon_{ind} = -N' \frac{d}{dt}(A' \mu_0 \frac{NI_0}{L} \sin wt) \qquad (10.8)$$

$$\varepsilon_{ind} = -\frac{NN' \mu_0 A' I_0 \omega \cos wt}{L} \qquad (10.9)$$

Experimental Procedure:

1. Connect one avometer in series to the field coil and the digital function generator in order to measure the current in the field coil.
2. Connect another avometer to the induction coil to measure the induced voltage. Set the avometer in AC mode to read the effective (rms) voltage and current values.
3. Make sure to set the offset of the function generator to zero.

Section 1

1. Place the d=41 mm-diameter, N=300-turn induction coil into the center of the field coil with the help of a ruler.
2. Using the "function" button of the digital counter, choose "frequency" option. Press "start" button once and adjust the frequency to 10.7 kHz by the "amplitude" knob. Make sure that the frequency scale is at 10^3 since the used frequency values is in the order of kHz.
3. By increasing the current of the signal generator from 2 mA to 40 mA by the "amplitude" knob measure the induced voltage in the induction coil by an avometer. Record your values to **Table 10.1**.

Section 2

1. Using the same configuration, arrange the frequency value to 1 kHz and the current in the field coil to 30 mA. Change the frequency of the field coil from 1 kHz to 10 kHz in 1 kHz steps by using the function generator and measure the induced voltage in the induction coil. Record your measured values to **Table 10.2**.

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Warning: The frequency scale in this experiment is between 1 kHz and 10 kHz. Below 0.5 kHz the coil becomes a short circuit. For frequencies above 12 kHz the sensitivity of the equipments is not guarenteed.

Section 3

1. Arrange the current in the field coil to 30 mA and the frequency of the function generator to 10.7 kHz.
2. Measure the induced voltage for each induction coil with 41 mm diameter and different number of turns and record your values to **Table 10.3**.

Section 4

1. Measure the induced voltage for each induction coil with 300 turns and different diameters and record your values to **Table 10.4.**

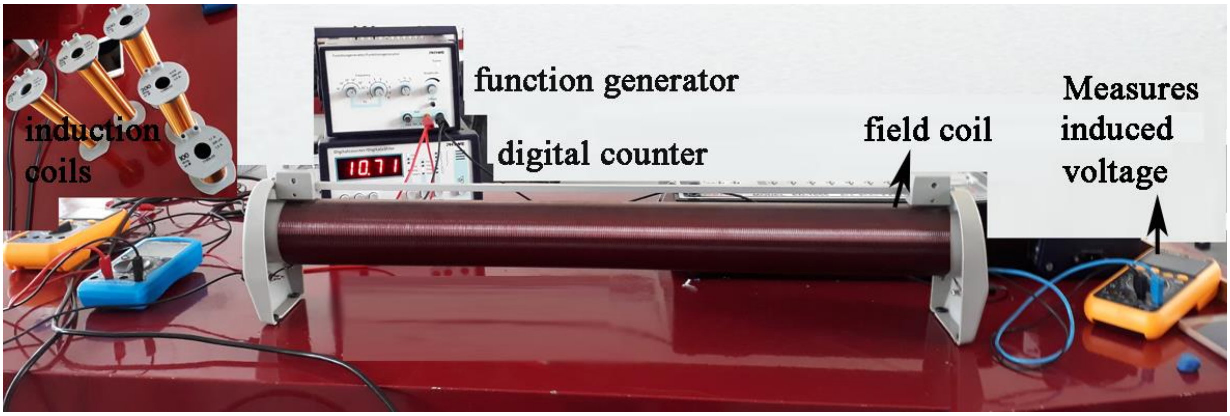

Figure 10.1 Set up of the magnetic induction experiment.

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EXPERIMENT 10

Magnetic Induction

DATE :

GROUP ID :

Student ID	Name Surname	Signature

Experiment Expectation	

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CALCULATIONS and RESULTS:

Section 1

Table 10.1 Induced voltage values as a function of current at 10.7 kHz frequency for the induction coil with N=300 turns and d=41 mm diameter.

I (mA)	U (mV)
2.0	
4.0	
6.0	
8.0	
10.0	
12.0	
14.0	
16.0	
18.0	
20.0	
22.0	
24.0	
26.0	
28.0	
30.0	
32.0	
34.0	
36.0	
38.0	
40.0	

Section 2

Table 10.2 Induced voltage values as a function of frequency at 30 mA current for the induction coil with N=300 turns and d=41 mm diameter.

f (kHz)	U (mV)
1.0	
2.0	
3.0	
4.0	
5.0	
6.0	
7.0	
8.0	
9.0	
10.0	

Section 3

Table 10.3 Induced voltage values as a function of the number of turns of the induction coil at 10.7 kHz frequency and 30 mA current for the induction coil with d=41 mm diameter.

N'	U (mV)
300	
200	
100	

Section 4

Table 10.4 Induced voltage values as a function of the diameter of induction coils with N=300 turns at 10.7 kHz frequency and 30 mA current.

d (mm)	U (mV)
25	
32	
41	

DISCUSSION AND COMMENTS:

1. ***For Section 1,*** Plot the I (mA)-U(mV) and evaluate how the induced voltage change as the magnitude of the magnetic field increases.

2. ***For Section 2,*** Plot the f (kHz)-U(mV) and evaluate how the induced voltage change as the frequency of the magnetic field increases.

3. ***For Section 3,*** Plot the N'-U(mV) and evaluate how the induced voltage change as the number of turns of the induction coil increases.

4. ***For Section 4,*** Plot the d (mm)-U(mV) and evaluate how the induced voltage change as the diameter of the induction coil increases.

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