Lab: Electromagnetic Induction

(Read before coming to the lab)

Module: CAN102, Electromagnetism and Electromechanics

Lab Time: Week 10 Thursday for D2/2

Lab Room: IR112

Grouping: **5** students per team

Submission: **23:59 2024/05/07** for D2/2

ATTENDANCE in the laboratory is MANDATORY

You MUST have your attendance recorded to receive a mark.

Learning outcomes:

C. Apply knowledge of electromagnetic fields to solve electric and magnetic circuit problems.

D. Model electromechanical systems using motors, transformers, or generators.

E. Understand the measurement of electromagnetic fields and analyse the results.

ACADEMIC INTEGRITY

Your assignment **must be entirely your team's own work**. **ALL team members are responsible for the entire submission**. Plagiarism, copying, collusion, or dishonest use of data will be penalised. Penalties ranging from capped scores to an award of zero can be applied. Please refer to the University's Academic Integrity Policy on E-bridge for guidance. You may also contact the Module Leaders if you have any confusion relating to academic integrity. Be advised that more serious instances of academic infringement will be presented at exam boards, which can result in more serious actions.

LATE SUBMISSION POLICY

XJTLU policy is –5% per day up to a total of –25%. Work submitted more than five working days late will receive a grade of zero.

1. Equipment List

The following equipment is required to perform the experimental work and is detailed in Figure 1.

(a) NI ELVIS III Kit: Digital oscilloscope + cables
(b) Magnets (set of 5)
(c) 10 m long enamelled copper wire 0.6 mm diameter.
(d) 1 m long, 13 mm diameter plastic tube (wall thickness 1 mm)
(e) Sand paper
(f) Protective foam (To prevent damage to magnets)
(g) Protective gloves

Shared equipment among teams:

(h) Scissors
(i) Tape

Self-prepared equipment:

(j) Pen/Pencil
(k) 50 cm Ruler

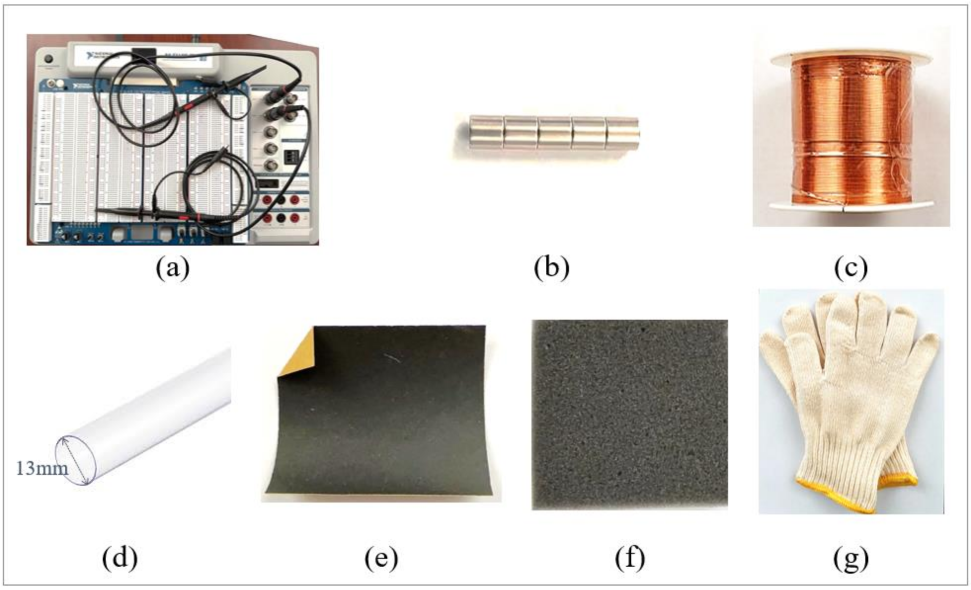


Figure 1: Equipment provided in the lab

2. Objectives:

To study the concept of electromagnetic induction and how it is defined.

To investigate the variation with time of the *emf* induced in a coil as magnets fall through it.

To analyse complex problems to reach substantiated conclusions using mathematics and engineering principles.

3. Experimental Section

3.1 Introduction

Many people believe that the battery or wall socket power outlet are the only ways to make a current flow and make their electronic devices work. Simply connecting a wire to an LED won't cause it to light up; there must be a power source, something to push the charges through the device. It turns out that batteries and power sockets are not the only ways to push charges and create a current. When a magnet moves through a loop of wire, the magnetic field experienced by the wire is changing, and this change causes charges within the wire to move. This is an exciting natural phenomenon allowing the energy of motion to be converted; moving the magnet produces electrical energy.

When current is created by moving a magnet through a coil, it is said to be an induced current. This phenomenon was discovered by both Michael Faraday and Joseph Henry in 1831. Michael Faraday published his discovery first, describing a fundamental principle of generation of an alternating electromotive force (*emf*) through electromagnetic induction.

The production of an induced *emf* in a circuit (conductor) is caused by a change in the magnetic flux linking the circuit. Faraday's law of induction states that a time-varying magnetic field produces an *emf* that may establish a current in a suitable closed circuit. This 'force' is merely a voltage that arises from conductors moving in a magnetic field or vice versa static conductors placed in changing magnetic fields. The linkage can be represented by the following equation:

$$emf = -N\frac{d\Phi}{dt}$$

where N is the number of turns of wire in a coil, and $\frac{d\Phi}{dt}$ is the rate of change of the magnetic flux through the coil.

The induced *emf* is proportional to the rate of change of magnetic flux through the N turns coil. The minus sign appears from Lenz's Law. It implies that the induced *emf* must be in the direction that opposes the change in the magnetic flux.

In addition, Faraday also discovered that the direction in which the magnet is moved will change the direction of the current. If you drop a magnet South end first through a coil, the direction of the current will be different to that if you dropped it North end first.

In this lab, students will use the digital oscilloscope to track the induced voltage in coils as a set of magnets moves through the plastic tube. Students will record and analyse a plot of *emf* versus time (and also calculate the area under the curve by integration), indicate the polarity of the given set of magnets, and indicate the factors which influence the amount of induced current. Figure 2 provides an indication of an experimental apparatus able to move a magnetic field in relation to a closed loop circuit in a repeatable and controllable manner.

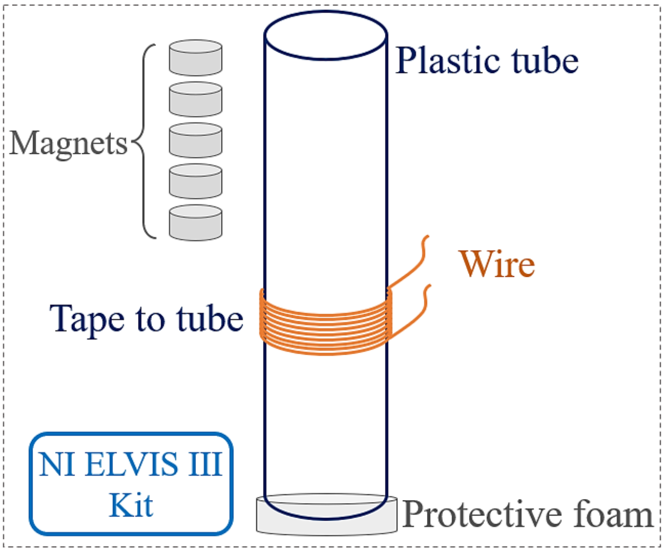


Figure 2: Basic experimental set-up

3.2 Safety Concerns

The magnets used are quite strong. It is very important to **be careful** when handling them. If two or more are brought close together and your finger is in the way it will be pinched.

Do NOT swallow the magnets.

Do NOT bring the magnets near your mobile phones, laptops, PC, iPad, etc.

3.3 Equipment Setup

The practical investigation of Faraday's law will utilise the equipment as set-up in Figure 3 below, which contains two coils that you will need to create yourselves.

Each team will be assigned its own set of parameters to construct the experiment. Ensure you follow your teams' assigned values for:

***N*1** – Number of turns for coil 1

***N*2** – Number of turns for coil 2

x – Distance from the top of the tube to the top of the first coil (coil 1)

y – Distance from the top of the first coil (coil 1) to the top of the second coil (coil 2)

***M*1 & *M*2** – Number of magnets to be used for magnet set 1 and magnet set 2

Step 1 – Prepare the copper wire

Use a pair of scissors to cut some copper wires of appropriate length to make the two coils (coil 1 and coil 2) to the specifications assigned to your team. The diameter of the tube is *d*=13 mm and it is recommended you leave approximately 30 mm at each end of the coil to make a connection, so the total length of wire required is $length_{total} = (N \times 2 \times \pi \times d) + 60$ mm.

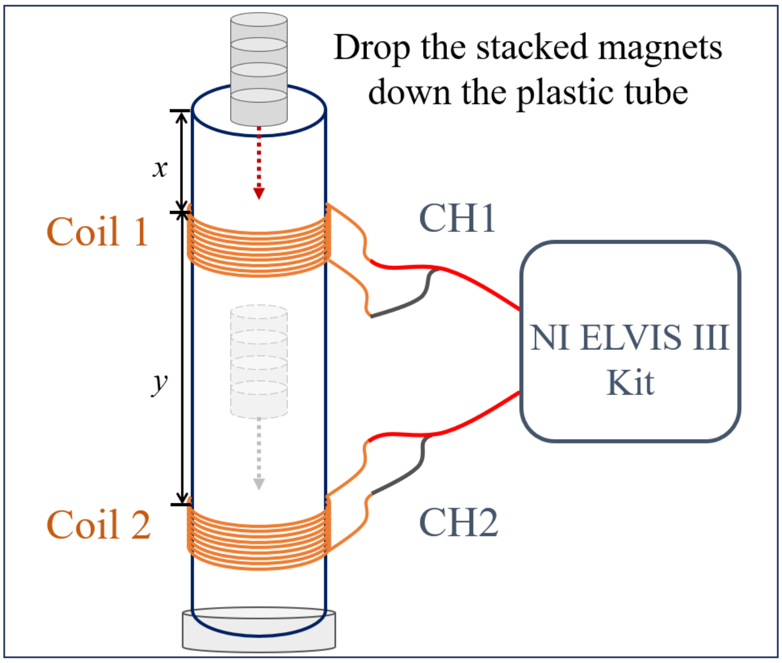


Figure 3: Investigation apparatus to be constructed.

Use sandpaper to strip the coating from each end of each copper wire (strip around 10 mm length), see Figure 4. The wire may look like pure copper, but it has a non-conductive coating that needs to be removed to make contact with the conducting copper core. You may wish to use the multimeter tool on the ELVIS III to check the connectivity between ends of the wire.

Note, please wear a pair of protective gloves when scraping the coating from the copper wire for safety purposes!

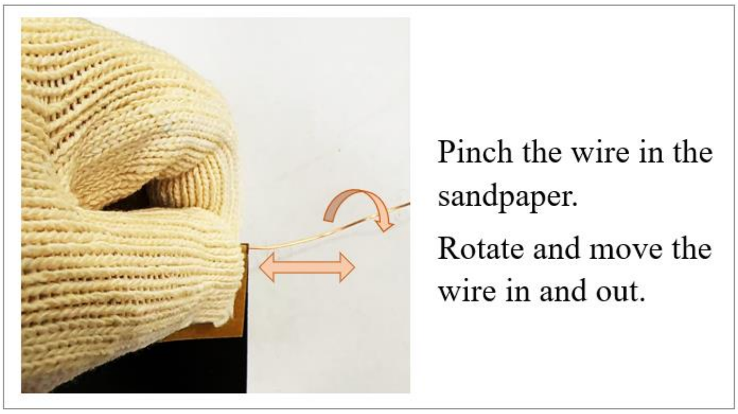


Figure 4: Stripping the enamel from the copper wire

Step 2 – Wind two copper coils

Create coil 1 (clockwise).

- Measure the distance *x* from the top of the tube and mark it with a pen/pencil (specified *x*, see Figure 3).
- Tape one end of the wire to the tube at the desired location leaving around 30 mm from the stripped end of the wire free from the tape, see Figure 5(a).

- Carefully wind the wire tightly around the tube in a **clockwise** direction (looking from the top of the tube).
- Count the number of turns as you go. Make sure you use the assigned specified number of turns $N1$.
- On completion of the coil, firmly affix to the tube with more tape. If you have made the correct number of turns, there should be approximately 30 mm of wire left to make connection Figure 5(b).

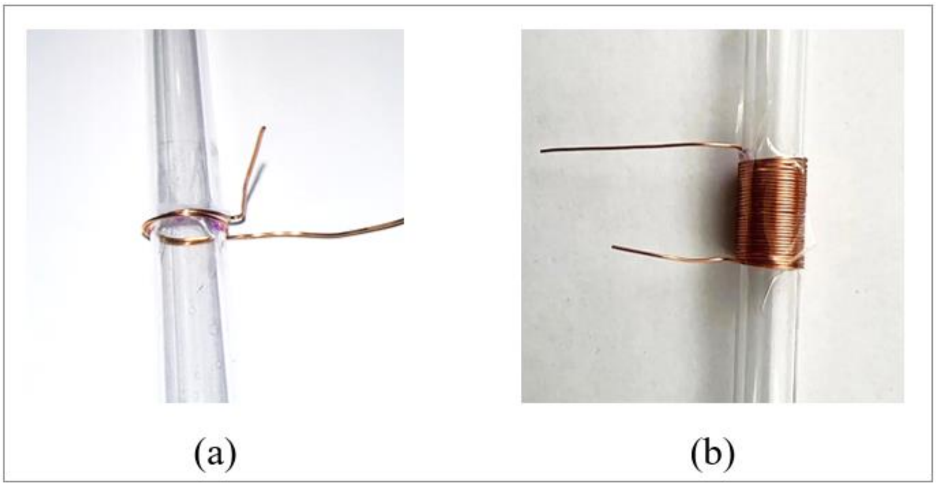


Figure 5(a) Initial turn taped to tube (b) Completed coil taped to tube

Create Coil 2 (counter clockwise)

- Measure a distance y from the top of coil 1 to determine where to commence coil 2 winding (Figure 3). The coil will be (x+y) mm from the top of the tube.
- Repeat the process used to create coil 1 but this time tightly wrap coil 2 around the plastic tube in a counterclockwise direction (seen from the top end of the tube). Count the number of turns as you go. Make sure you use the assigned specified number of turns $N2$.

Step 2 – Set up the measurement equipment

- Connect the two oscilloscope leads to the NI ELVIS III oscilloscope input points Channel 1 (ch 1) and Channel 2 (ch 2).
- Using the oscilloscope lead on ch 1, connect the probe to the top end of coil 1 and connect the ground to the bottom of coil 1.
- Using the oscilloscope lead on ch 2, connect the probe to the top end of coil 2 and connect the ground to the bottom of coil 2.
- To conduct measurements the plastic tube needs to be held in a vertical position with the protective foam placed at the bottom, see Figure 6 (If the magnet hits the bench without the foam, it may break). Note: you may need to support the oscilloscope leads by hand depending on how well the coils have been fixed to the plastic tube.

Figure 6: Experimental Apparatus

Step 3 – Measurement Set-Up and Electrical Connections

Start the "Measurements Live" Software and select "**Measure**" (see Figure 7(a) and (b)). From the instrument menu, shown in Figure 7(c), select the "**Oscilloscope**".

(a) 

(b) 

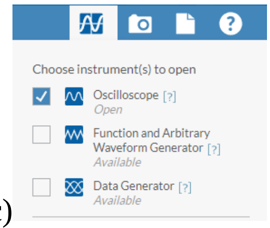
(c) 

Figure 7 (a) Software shortcut (b) Measure application (c) Instrument Panel Selection

Set the oscilloscope with the following settings and as shown in Figure 8.

Trigger: **Single** (This will capture waveforms once and hold them, you need to press Run each time you want to capture a new trace).

Type: Analogue edge

Source: Channel 1

Slope: Rising

Level: around 10 mV at the beginning

(This value can be adjusted to better fit your experiment during the lab session. The main consideration is that you should set this as small as possible, such that the oscilloscope does not trigger without the magnets falling in the tube)

Horizontal & Acquisition

Time/div: 50 ms (you may adjust this once the traces have been captured.

Channel 1

Volts/div: 50 mV (starting value may need to be adjusted)

Channel 2

Volts/div: 50 mV (starting value may need to be adjusted)

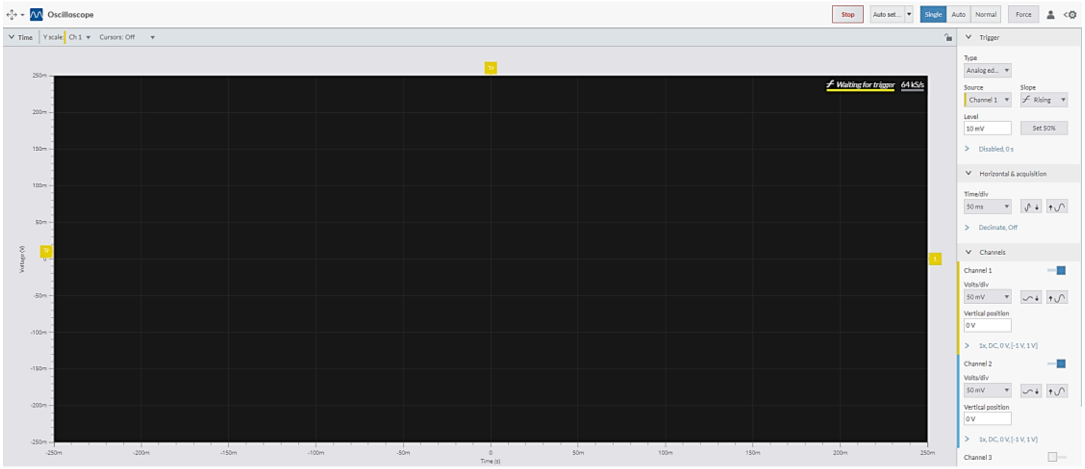


Figure 8: (a) Instrument Menu (b) Oscilloscope Instrument Panel

Step 4 – Experiment 1 and Measurements

After checking your setup, Click 'RUN' on the oscilloscope panel. Drop your **magnet set 1** with ***M*1** magnets through the plastic tube. Make sure you drop it from the top of the plastic tube. Observe and record the traces/data on ch 1 and ch 2, and complete the tasks **B-1~B-5**.

Step 5– Experiment 2 and Measurements

Drop your **magnet set 2** with ***M*2** magnets through the plastic tube with coil 1 wrapped on the tube only. Make sure you drop it from the top of the plastic tube. Observe and record the traces/data on ch 1, and complete the tasks **B-6 and B-7**.

Step 6– Experiment 3 and Measurements

Drop your **magnet set 2** with ***M*2** magnets through the plastic tube with coil 1 and coil 2 wrapped on the tube (Figure 3). Observe and record the traces/data on ch 1 and ch 2, and complete the task **B-8**.

Step 7 – Save screenshot and Export data

You can click the camera button on the top right of the Instrument Panel Selection to capture the displayed traces. You may need these for completing some tasks in the assignment.

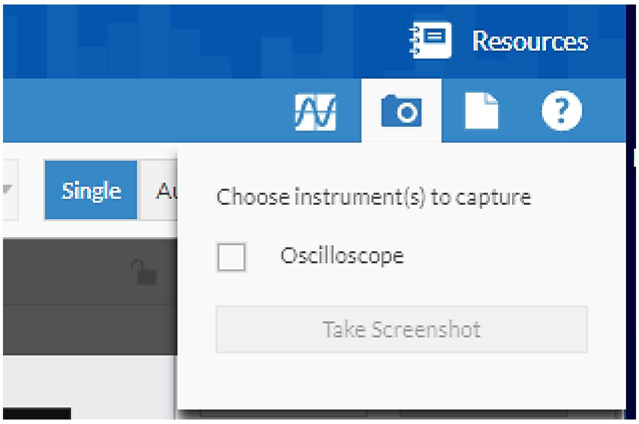


Figure 9: (a) Capture figures of the traces

The page button next to the camera on the Instrument Panel Selection allows you to export the detailed data of the measured voltages vs time. You may need these for completing some tasks in the assignment.

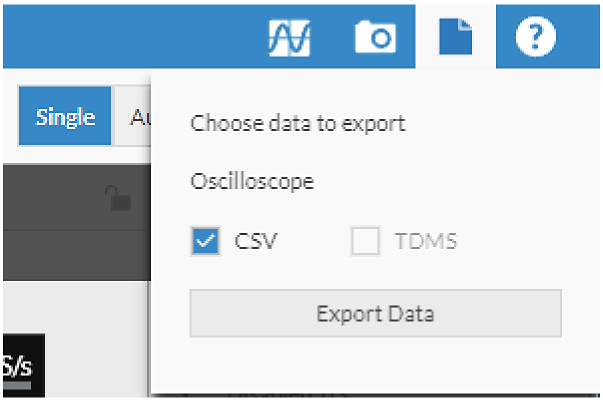


Figure 10: Export data of voltages vs time

Step 8 – Straighten up the lab station

Once you have completed the experiment, tidy up your bench and shut down the PC.

Additional Information

Note that the values of all parameters mentioned here will be provided in the 'D22_Assignment.pdf'. Your team should complete all tasks in the document 'D22_Assignment.pdf' and it will be released on Core in Week 9 Saturday.