Electromagnetic Induction

Purpose

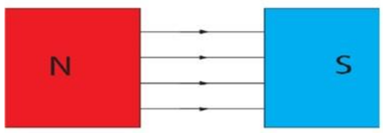
Using the "Borderless Lab 365" platform to study the effects of (i) *magnet thickness* (related to the intensity of magnetic field), (ii) *number of coil turn* and (iii) *rotation speed* on the *induced electromotive force*.

Theory

- Electromagnetic induction is the production of an electromotive force (emf) across a *conductor* in a *changing magnetic field*.

- According to **Faraday's law** $\varepsilon = -\frac{d\varphi}{dt}$ (where ε is the induced emf and ϕ is the magnetic flux enclosed by the circuit), the induced emf in any closed circuit is equal to the rate of change of the magnetic flux enclosed by the circuit. Thus, Faraday's law of induction makes use of the concept of using magnetic flux through a region of space enclosed by a wire loop.

- Magnetic field is existed between two pieces of magnet. Magnetic field lines are a visual tool used to represent the magnetic fields. It always runs from North to South (as shown in Fig. 1a). When a coil (or conducting surface) is inserted into the magnetic field, magnetic flux will be generated. By definition, magnetic flux through a surface is the surface integral of the normal component of the magnetic field over that surface i.e. measurement of the total magnetic field (or number of field lines) which passes through a given area. In this experiment, the configuration of the magnet and coil is shown in Fig. 1b.



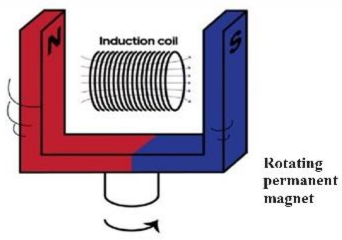


Fig. 1a Fig. 1b

- Generating an emf through a variation of the magnetic flux through the surface of a wire loop can be achieved in several ways:
  A) the magnetic field changes (e.g. an alternating magnetic field, or moving a wire loop towards a bar magnet or vice versa, where the magnetic field is stronger),
  B) the wire loop is deformed and the surface changes,
  C) the orientation of the surface changes (e.g. spinning a wire loop into a fixed magnetic field), and
  D) any combination of the above.

- In this experiment, we will change the magnetic flux using a rotating magnet. The magnitude of the induced emf varies with the cutting angle between the coil and the magnetic field lines. For example, when the coil is parallel to the magnetic field lines (as shown in Fig. 1b), the magnetic flux is maximum and the rate of change of the magnetic flux momentarily will be zero. Thus, the induced emf at this position = 0. On the other hand, when the coil is perpendicular to the magnetic field lines, the magnetic flux is zero and the rate of change of the magnetic flux momentarily will be maximum. Thus, the magnitude/frequency of the induced emf will be depended on the *rotation speed of the magnet*, *the strength of the magnet* and *the turns of the coil*.

- The magnetic induction can be applied in electric applications, such as generator and electric motor.

Apparatus

- “Borderless Lab 365” Platform
- Magnets with three difference thicknesses: 2mm/ 3mm/ 5mm (thicker magnet will produce a stronger magnetic field in between the magnets. *The thinnest magnets are located on the top of the array*.)
- Coil with different turns: 100/200/300 (turns)
- Motor that provide Rotation speed with different rpm (rotation per minute): 30-300 (rpm)

Procedure

1. Log in the experiment module “EM induction” on the Borderless Lab 365 platform. https://labxra.edu.hk/remotelab/
2. Select the magnet thicknesses, coil turns and rotational speeds by pressing corresponding button.
3. Press “MEASURE” to record the emf produced by the coil.
4. Result will be displayed in the graph. The graph should be a sine curve. From the curve, please find the peak emf and period of the sine curve.
5. Download the graph by clicking “Menu” and choose a format (.svg, .png, .csv).

6. Repeat step 2 to 4 under different conditions, select at least 3 different rotation speeds and complete the tables in the Data Section.
7. Press “LOGOUT” when you complete the experiment.

Data

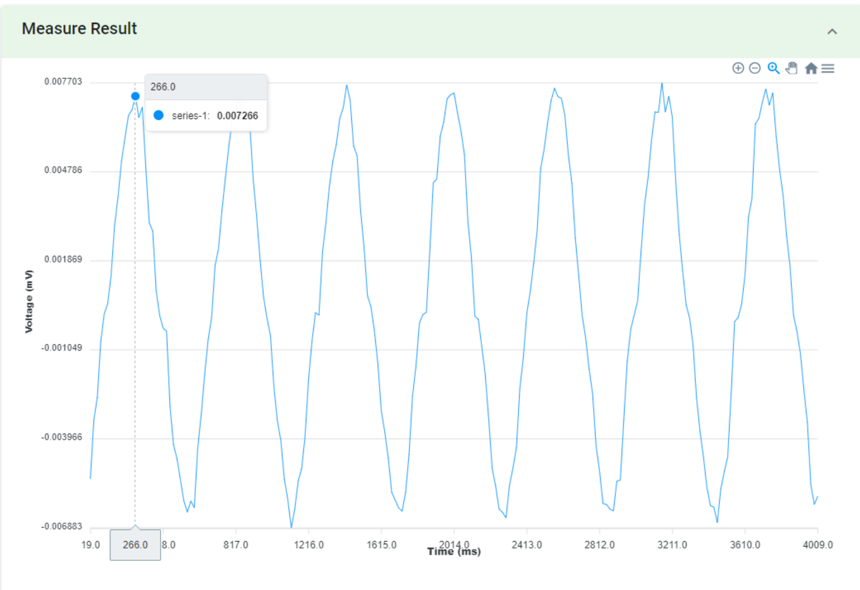
Magnet Thickness: ________________________ mm

Coil turns: ________________________ turns

Input Rotational Speed: ________________________ rpm

Sketch the waveform of the emf produced by the coil in the graph paper below, i.e. the emf vs time graph observed in the screen. (4 marks)

From the graph shown in the screen, you can use the cursor to find out the values of the peak position as shown in the following figure. The top value is for the x-axis (in ms) while the bottom value (marked with series-1) is for the y-axis (in mV).



Please find the following information from your graph shown on the screen (3 marks):

Period : ________________ ms

Induced emf: ________________ V

Estimated rotational speed ω: ________________________ rpm

Remarks:

1. You can estimate the rotational speed by measuring the period of the oscillation.
2. To find the induced emf, you should find the difference between the maximum value and the minimum value of a single peak (i.e. within the same period). To obtain a better result, it is suggested to find the difference values for at least three peaks and take the average.
3. Notice that the maximum value is not the same as the absolute value of the minimum value i.e. the peak is not symmetrical along the y-axis. This means that there is a zero offset in the measured output emf.

Based on the waveforms obtained for different settings, please fill in the tables below (20 marks):

Thickness of magnet = 2mm

	ω_1(rpm)*	ω_2(rpm)*	ω_3(rpm) *
100 Turns	mV	mV	mV
200 Turns	mV	mV	mV
300 Turns	mV	mV	mV

*You can choose any three different rotational speeds values (within 30 to 300 rpm). It is suggested to have $\omega_1 > \omega_2 > \omega_3$, and their values should not be too close to each other.

Thickness of magnet = 3mm

	ω_1(rpm)	ω_2(rpm)	ω_3(rpm)
100 Turns	mV	mV	mV
200 Turns	mV	mV	mV
300 Turns	mV	mV	mV

Thickness of magnet = 5mm

	ω_1(rpm)	ω_2(rpm)	ω_3(rpm)
100 Turns	mV	mV	mV
200 Turns	mV	mV	mV
300 Turns	mV	mV	mV

Discussion

1. (3 marks) Find out how the induced emf is affected if
   a. Rotational magnet is moved with a higher speed,
   b. Stronger magnets (magnet with larger thickness) are used,
   c. Coil with more number of turns is used.

What happens to the period of the induced emf

2. Write down the energy conversion involved in the experiment (1 mark).
3. If the coil is an incomplete circuit, is there any induced emf or induced current in the coil when the magnet is rotating? Explain. (1 mark)
4. What are the possible errors of the experiment? (1 mark) (hint: other source of magnetic field beside the rotating magnets, uniformity of the coil such as the area of each turn, etc.)
5. Please explain what addition parameter(s) of the experiment is needed to determine the magnitude of the magnetic field. (1 mark)
6. From the graph shown in the data part, measure the period of the oscillation. Based on this oscillation period, find the rotational speed of the magnets. Compare this value with the input value? Any difference? (1 mark)