Faraday's Law of Electromagnetic Induction

The aim of this experiment is to investigate quantitatively the relationship between induced voltage and magnetic flux, time and the number of turns in a coil of wire.

Introduction

Michael Faraday (1791–1867) discovered a relationship between a changing magnetic flux, Φ B, and the induced EMF within a conductor, ε. Known as Faraday's law, this relationship is defined by two key elements: the number of turns in a coil, N, and the change in magnetic flux, $\Delta\Phi$ B.

In this activity, Faraday's law will be investigated by using magnets of different strength and increasing the rate at which the magnet passes through the coil.

Materials

- PASCO Capstone or SPARKvue
- Wireless voltage sensor
- 200, 400 and 800-turn coils (or other coils of known number of turns as available)
- neodymium magnets
- plastic tubes with lids (empty blood-test tubes from a pathology lab are ideal)
- retort stand and clamp
- paper and tape
- no-bounce or foam pad (optional)

Method

PART A • VARYING THE NUMBER OF TURNS

1. Connect the voltage sensor to the PASCO Capstone or SPARKvue following the manufacturer's guidelines and start a new experiment. Set the sample rate to at least 200 Hz and display a graph of voltage versus time.
2. Mount the 200-turn coil to the retort stand using the clamp, so that it is approximately 40 cm above the benchtop. If a no-bounce pad is available, place it under the coil to soften the fall of the magnet/s.
3. Connect the voltage sensor to the coil.
4. What do you expect the voltage–time graph to look like when the magnet is dropped through the coil? Before continuing, sketch a prediction of a voltage versus time graph.
5. Hold the magnet just above the opening of the coil, press start and then drop the magnet through the coil. Stop collecting immediately after.

6. Replace the coil with the 400-turn coil (or the coil with the next most turns) and then repeat the data collection. Do the same for each coil.
7. Display the data on one graph, annotating each curve to identify the number of turns.

PART B • VARYING THE NUMBER OF MAGNETS

Use the same set-up for this part as in Part A, but use only the 200-turn coil (or the smallest number of turns available)

1. Hold the tube containing one magnet just above the coil opening. Start the data-collection system and then drop the magnet through the coil. Stop collecting immediately after.
2. Repeat with tubes containing two, three, four and five magnets, as available.
3. Display the data runs on the one graph, annotating each to identify the number of magnets.

PART C • VARYING THE RATE OF CHANGE OF FLUX

Use the same set-up for this part as in Part A, but using only the 200-turn coil (or the smallest number of turns available) and a tube with a single magnet.

1. Roll up a piece of paper into a tube, and tape it securely. The tube should be wide enough to allow your magnet to pass through freely, but narrow enough to guide the magnet through the coil.
2. Mark four equally spaced positions on the tube and slide the tube into the coil so that the first mark is showing just above the coil opening.
3. Hold the magnet just above the tube opening. Start the data-collection system and then drop the magnet through the coil. Stop collecting immediately after.
4. Slide the paper tube down into the coil until the next mark on the tube is just above the opening of the coil and repeat the data collection. Repeat the process for the remaining positions marked on the paper tube.
5. Display the data on one graph, annotating each to identify the height from which the magnets were dropped.

Results

PART A • VARYING THE NUMBER OF TURNS

1. If a changing magnetic field causes charges to move in a conductor, and charges moving in a conductor give rise to a magnetic field, what will be the orientation of the induced magnetic field relative to the original changing magnetic field?
2. Sketch a graph of the induced voltage versus time for the different number of turns in the coils.

9/899 wellington road rowville 3178 victoria australia
p 03 9764 3638 e contact@ciderhouse.com.au
www.ciderhousetech.com.au

PART B • VARYING THE NUMBER OF MAGNETS

1. Sketch a graph of the induced voltage versus time for a different number of magnets.

PART C • VARYING THE RATE OF CHANGE OF FLUX

1. Sketch a graph of the induced voltage versus time for each of the different drop heights.

Discussion

1. How did your prediction compare to the actual voltage versus time graphs?
2. Describe the relationship between the number of turns in the coils and the peak voltages observed.
3. Describe the relationship between the strength of the magnets used and the peak voltages observed. What could be measured to give a more precise relationship?
4. Describe the relationship between the height above the coil from which the magnet fell and the peak voltages observed. What could be measured to give a more precise relationship?
5. The second peak of the voltage curve is always in the opposite direction to the first peak and is also a slightly larger peak. Describe why this is the case.

Acknowledgements

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