ScienceCube

Electromagnetic Induction

1. **Understand and explain the principle of induced electromotive force (EMF) in a solenoid.**
2. **Measure and explain the current in a solenoid caused by electromagnetic induction and mutual induction.**

Fundamental Concept

1. **Faraday's Law**

When there is a change in magnetic flux through a solenoid, an EMF is induced. The magnitude of the EMF is proportional to the rate of change of the magnetic flux through the solenoid and is given by:

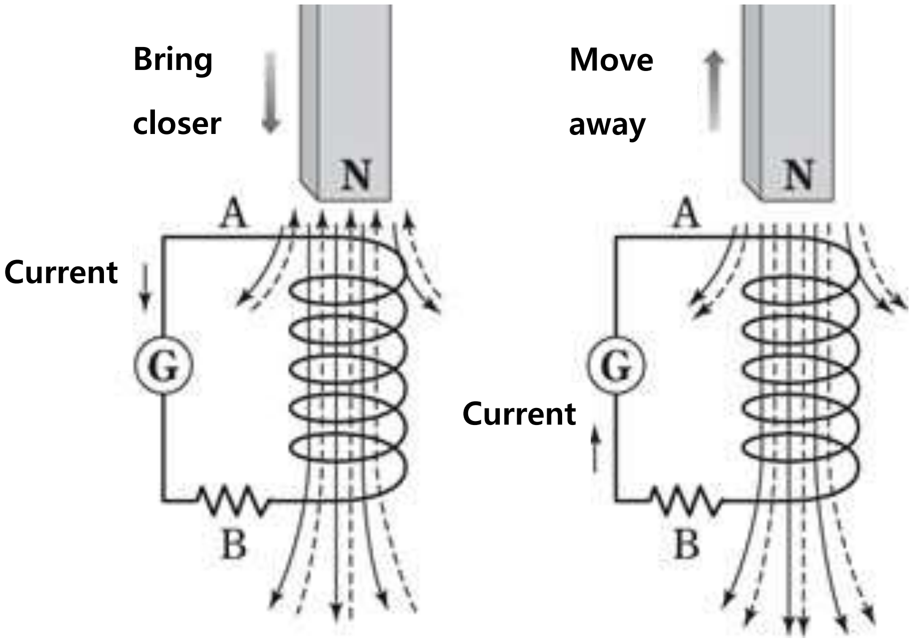
$$\varepsilon = -n\frac{\Delta\emptyset}{\Delta t}$$

where ϵ is the induced EMF, n is the number of turns in the solenoid, $\Delta\Phi$ is the change in magnetic flux, and Δt is the time interval.

Faraday systematically summarized the experimental results between induced EMF and magnetic flux changes into Faraday's Law. Induced EMF is proportional to the time rate of change of magnetic flux through a closed loop and to the number of turns of the solenoid.

No EMF is induced if there is no change in magnetic flux.

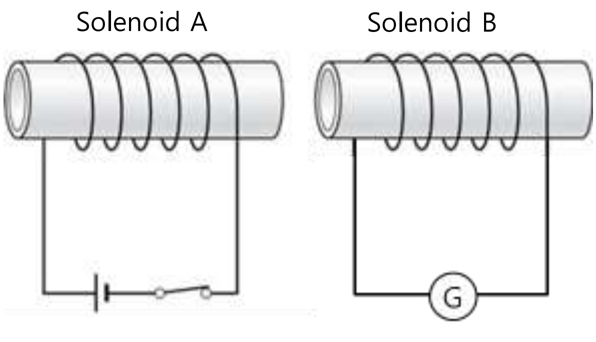
2. **Lenz's Law**



The direction of the induced EMF is such that it opposes the change in magnetic flux that caused it. If the magnetic flux through the solenoid increases, the induced EMF will create a current that generates a magnetic field opposing the increase. Conversely, if the magnetic flux decreases, the induced EMF will create a current that generates a magnetic field opposing the decrease.

3. **Mutual Induction**

The phenomenon where a change in current in one solenoid induces an EMF in a neighboring solenoid. When the switch in solenoid A is opened or closed, the needle of the galvanometer connected to solenoid B moves, indicating an induced EMF due to the change in current through solenoid A. The induced EMF in solenoid B is proportional to the time rate of change of current in solenoid A:



$$E_2 = -M\frac{dI_1}{dt}$$

(where E is the induced EMF, M is the mutual inductance, I is the current, and t is the time.)

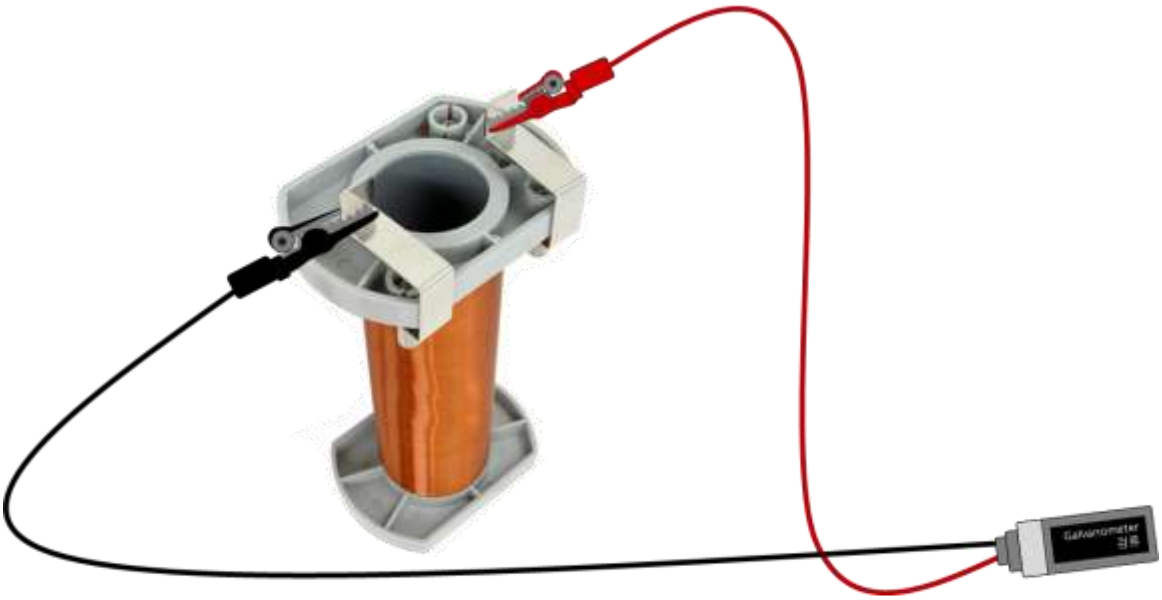
Experiment

Materials Needed

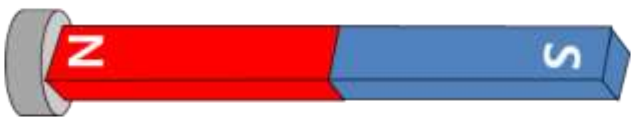
Interface, Science# program, Galvanometer, Two solenoids (that can overlap), Switch, Bar magnet, Alligator clip wires (4), Power supply (15V), Neodymium magnets (3))

Experimental Setup

1. Connect the solenoids and galvanometer as shown in the diagram.

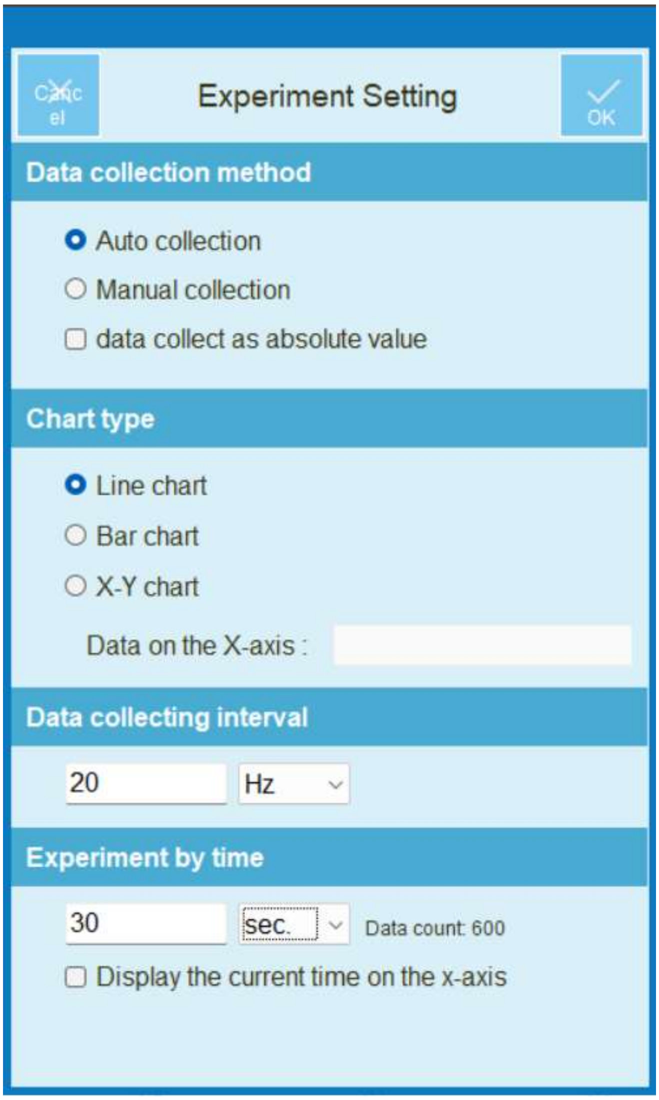


2. Attach a neodymium magnet to the N pole of the bar magnet.



Interface Setup

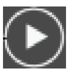
1. Run the Science# program.
2. Connect the galvanometer to the interface.
3. Press to set up the experimental environment as shown or press for automatic setup.

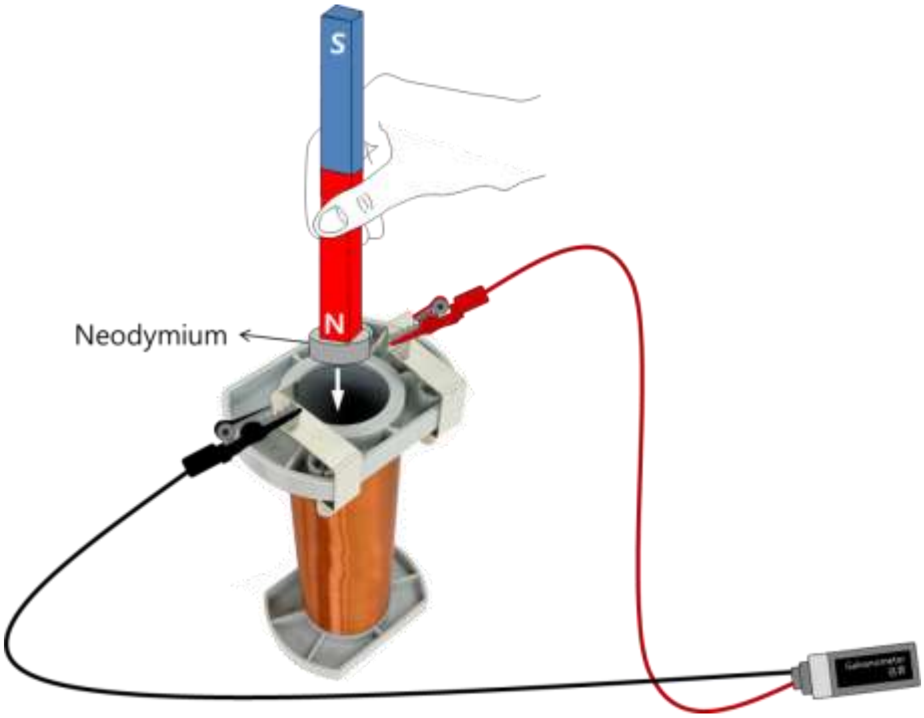


 Automatic setup

Data Collection

[Experiment 1] Electromagnetic Induction

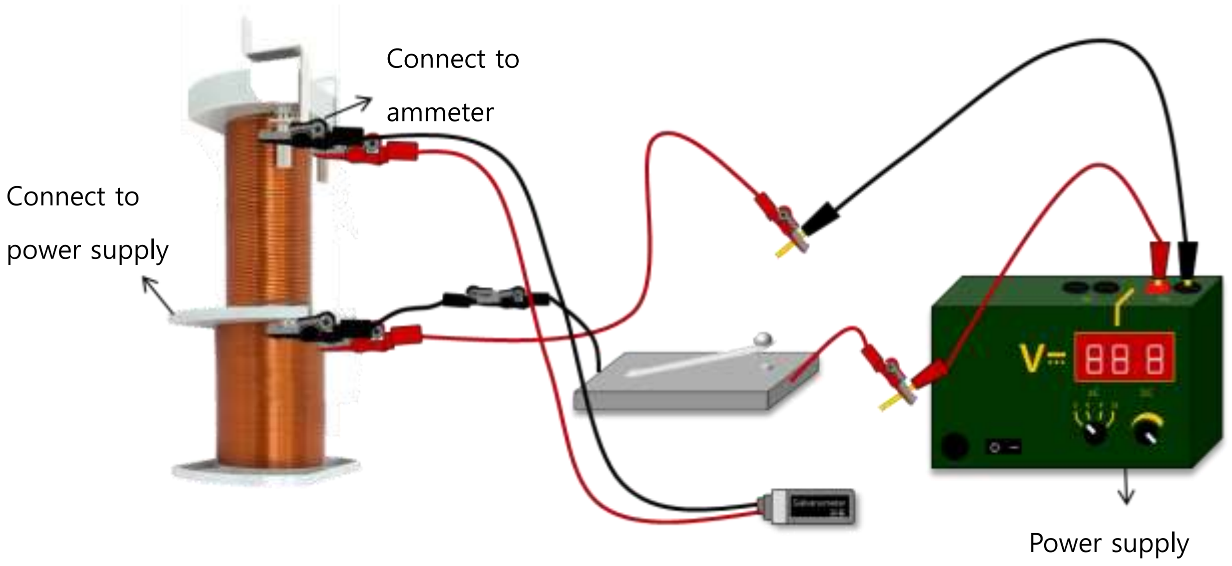
1. Press  to start data collection.



2. Insert and remove the bar magnet with its N pole facing down into the solenoid at a constant speed and measure the current.
3. Insert the bar magnet slowly and then quickly into the solenoid with its N pole facing down and measure the current for each case.
4. Increase the number of neodymium magnets to 2 and then 3, and measure the current induced in the solenoid for each case.

[Experiment 2] Mutual Induction

1. Overlap two solenoids of different sizes.
2. Assemble the circuit using a switch, galvanometer, and power supply as shown in the diagram.
3. Connect the power supply and switch in series with the solenoid at the bottom, and connect the galvanometer to the other solenoid.
4. Apply a DC voltage of 15V to the circuit using the power supply.



5. Press ▶ to start data collection.
6. Measure and record the current when the switch is closed, remains closed, and is opened..

Data Analysis

Recording Data

[Experiment 1] Electromagnetic Induction

< Current According to the Magnet's Direction>

1. Record the current for different magnet directions..

Magnet Direction	Inserting	Removing
Current (mA)		

< Current According to the Magnet's Speed>

2. Record the current for different magnet speeds.

Magnet Speed	Inserting Slowly	Inserting Quickly
Current (mA)		

< Current According to the Number of Magnets>

3. Graph the current for different numbers of magnets and complete the table.

Number of Magnets	1	2	3
Current (mA)			

[Experiment 2] Mutual Induction

1. Graph the current induced when the switch is closed, remains closed, and is opened, and complete the table.

Situation	Closing Switch	Switch Remains Closed	Opening Switch
Current (mA)			

Data Application and Extension Activities

1. When inserting and removing the magnet with the same pole, is the sign of the current the same? What does this sign signify?

2. Explain how the current in the solenoid changes with the speed of the magnet's movement.

3. Explain the changes in current in the solenoid with different numbers of magnets and the reason for these changes.

4. Describe methods to induce current in the solenoid.

5. Based on the results of the mutual induction experiment, explain why the current behaves as observed when the switch is closed, remains closed, and is opened.


Report
(For Teachers)


Report
(For Students)