INDUCED ELECTROMOTIVE FORCE

Short description
The purpose of this experiment is to study how currents can be induced in conductors by the presence of magnetic fields that change with time.

Equipment
- Pair of coaxial cylindrical coils (solenoids)
- Two banana cables, one magnet, Galvanometer

Theory
According to Faraday's Law of induction a changing magnetic field induces an electric field. For an electrical circuit consisting of \( N \) identical turns of wire, the magnitude of the induced emf \( \Delta V \) is proportional to the number of turns \( N \) and to the rate at which the magnetic flux is changing:

\[
\Delta V = -N \frac{\Delta \Phi_B}{\Delta t}
\]

where \( \Phi_B = B A \cos \theta \) is the total flux: \( B \) is the magnetic field strength, \( A \) is the area of the coil, and \( \theta \) the angle between \( B \) and the normal to the coil area. The minus sign indicates that the induced current in the circuit produces an induced magnetic field which opposes the change in flux (Lenz's Law). The flux can vary by changing \( B, A, \) or \( \theta \).

Procedure
1. Connect the cylindrical coil (solenoid) to the galvanometer as shown in Fig. 1 below. The coil is connected to a galvanometer (a sensitive current meter).
Thrust the N-pole of the bar magnet into and then out of one end of the coil. Describe the effect that the direction of motion of the magnet has on the direction of the induced current.

1.1 What effect does the speed of the magnet have on the magnitude of the induced current?

1.2 How the direction of the induce current depends on the motion of the magnet?

2. Repeat step 1, holding the magnet stationary while moving the coil. Describe your observations.

2.1 What effect does the speed of the coil have on the magnitude of the induced current?

2.2 How the direction of the induce current depends on the motion of the magnet?

3. What is the effect of holding the magnet stationary inside the stationary coil?

4. Repeat step 1. using the S-pole of the bar magnet. What effect does the polarity of the magnet have on the direction of the induced current? Compare with step 1.

Simulations

1. To explore the Lenz Law open this applet.
Construct a qualitative graph of flux in the loop vs. time

\[ \Phi(B) \]

- \[ t \]

Construct a qualitative graph of induced current in the loop vs. time

\[ i \]

- \[ t \]
2. To explore the Lenz Law open this [applet](#). Draw the induced current in each loop at time

\[ t = 0.5s \]

\[ t = 4.5s \]

**Questions**

1. Refer to Fig. 1 on page 1. The coil is connected to a galvanometer. If the magnet moves to the left, what is the direction of the current through the galvanometer (G)? Left or right?

2. Now assume the magnet is replaced with another coil connected to a battery, as shown in Fig. 2

2.1 Which end of the coil with the battery becomes the North Pole? Left or right?

2.2 Which end of the coil with the galvanometer becomes the North Pole? Left or right?

2.3 What will be the direction of the current through the galvanometer (G) immediately after the switch connecting the battery is closed? Left or right?
3. A square coil of side 5.0 cm and resistance R = 100 Ω contains 100 loops and is positioned perpendicular to a uniform $B$ field of 0.60 T. The coil is quickly removed from the $B$ field in 0.1 s.

3.1 Calculate the change in the flux

3.2 Calculate the induced emf

4. A loop of wire is placed above a long wire. The switch is suddenly closed and a current $I$ flows through the long straight wire.

3.1 Draw in the center of the loop, the direction of the $B$ field produced by the straight wire.

3.2 Draw in the center of the loop, the direction of the induced $B$ field.

3.3 Draw the direction of the induced current in the loop.

3.4 Draw on the straight wire, the direction on the induced $B$ field.

3.5 Draw the direction on the magnetic force acting on the long wire due to the induce $B$ field.