EXPERIMENT – 6
STUDY OF ELECTROMAGNETIC INDUCTION- FARADAY'S LAWS

AIM

1. TO STUDY THE INDUCED EMF AS A FUNCTION OF VELOCITY OF THE MAGNET PASSING THROUGH THE COIL.

2. TO STUDY THE CHARGE DELIVERED DUE TO ELECTROMAGNETIC INDUCTION.

APPARATUS

The experimental setup consists of a permanent magnet mounted on an arc of a semicircle (D shaped) of radius 40cm, measurement board consisting of voltmeter, milliammeter, resistance, condenser and diode The arc part of rigid frame of aluminum and is suspended at the center of the arc so that the whole can oscillate freely in its plane. (Fig. 1.)

THEORY

Weight(A,A) have been provided on the diagonal arm, so that by altering positions the time period of oscillation can be varied from about 1.5 to 3 sec. Two coils of about 10,000 turns of copper wire loop the arc so that the magnet can pass freely through the coil. The two coils are independent and can be connected either in series or parallel. The amplitude of the swing can be read from the graduated circle by the pointer, when the magnet moves through and out of the coil the flux of the magnetic field through the coil changes, inducing the emf.
On the panel of the measurement board one voltmeter with four range 0-2.5V, 5V, 10V, 20V and one ammeter with two ranges 1mA, 2.5mA are provided. Board also has four different value condensers five resistances and two diodes and one SPST for performing experiments.

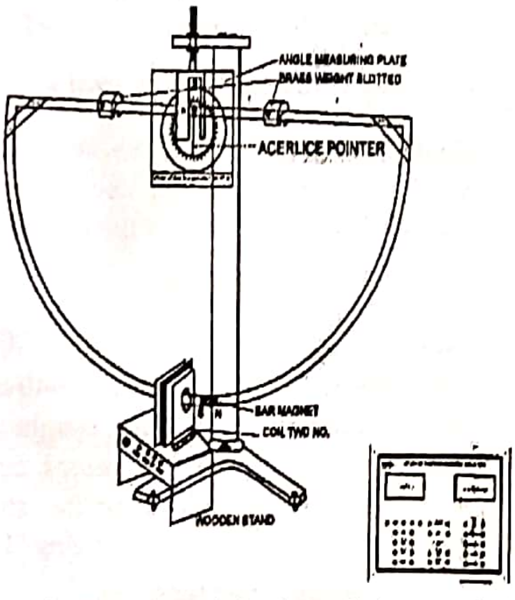


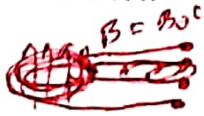
Fig. 1. Experimental setup of Faraday's law

Features

1. Mechanical part consisting of a permanent magnet mounted on an arc of semicircle of radius 40cm. The arc is part of a rigid frame of aluminum and is suspended at the centre of arc so that the whole frame can oscillate freely in its plane. Weights have been provided on the diagonal arm, so that by altering their position, the time period of oscillation can be varied from about 1.5 to 3 sec. Two coils of about 10,000 turns of copper wire loop the arc, so that the magnet can pass freely through the coil. The two coils are independent and can be connected in series or parallel.

2. Measurement board consisting of voltmeter, milliammeter, resistance, condenser and diode.

$B = B_0 \cos \omega t$



BASIC PRINCIPLE

The basic principle of generation of alternating emf is electromagnetic induction discovered by Michael Faraday. The phenomenon is the production of an induced emf, V_{emf} (in volts) in a closed circuit is equal to time rate of change of magnetic flux linkage by the circuit. Faraday's law of induction tells us that the induced emf, "V_{emf}" is given by

$$V_{emf} = -\frac{d\lambda}{dt} = -N\frac{d\emptyset}{dt} \text{.............................} (1)$$

Where$\lambda = N\emptyset = flux\ linkage$ and $\emptyset$ represents flux through each turn and N is the number of turns.

The negative sign shows that the induced voltage acts in such a way that it opposes the flux producing it. This is known as Lenz's law.

STUDY OF ELECTROMAGNETIC INDUCTION AND VERIFICATION OF FARADY'S LAW.

This experiment is performed in two parts.

Part 1.To study the induced emf as a function of velocity of the magnet passing through the coil.

Magnet NS pass through the coil C (by using coil 1 OR 2) with varying velocities (Fig.2.) An aluminum frame can swing about a pivot O, its period adjustable by sliding the loads A, A. If D is released from angle $\theta_0$from the equilibrium, the velocity V_{max} with which the magnet passes through the coil is given by

$$V_{max} = \frac{4\pi}{T}\sin\frac{1}{2}\theta_0 \text{.......................} (2)$$

Where P is radius of D-shape arc (=40 cm).

The magnetic flux (fig.3.) through the coil (Φ) changes as the magnet NS passes through it also two pulses with opposite signs are generated in the coil for each swing. The peak E_0 corrosponds to maximum $\frac{d\Phi}{dt}$.

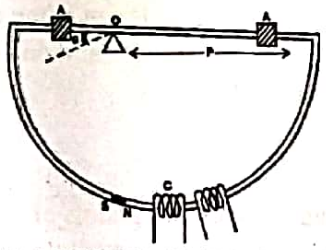


Fig.2. THE MECHANICAL PART WITH MAGNET NS PASS THROUGH COIL 'C' WITH A MEASURABLE VELOCITY

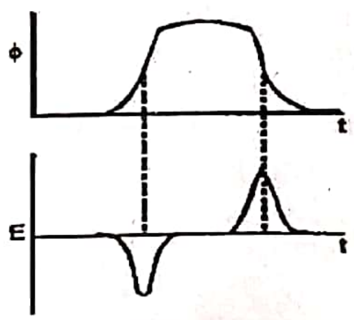


Fig. 3. Time Variation of Magnetic Flux Φ and emf E

PROCEDURE

1. Make the circuit as shown in Fig.4. Keep switch S in OFF position. C ≈ 100μF and R1 ≈ 500Ω. (here R1 represents the internal resistance of the coil and the forward resistance of the diode D.) At each swing the diode permits the capacitor to gain a charge once. The charging time RC being 50 ≈ ms. and the pulse width τ (Fig.3) being a little smaller, the capacitor reaches the E_0 value in a few swings.

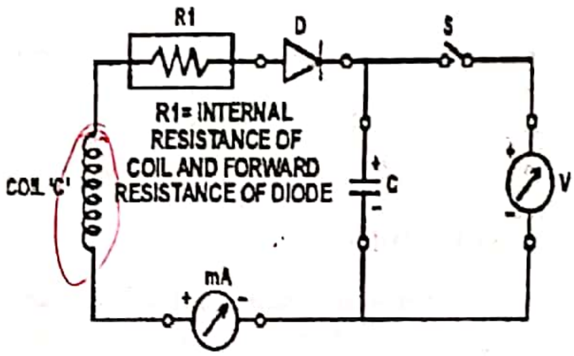
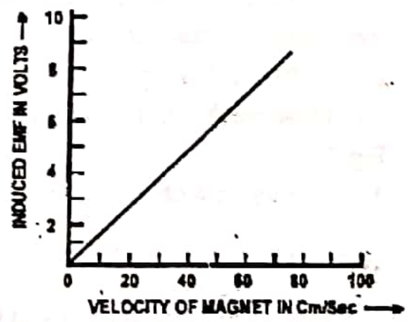


Fig. 4. Circuit Diagram for measuring v_{max}

2. When the milliammeter shows no more kicks, it means the capacitor C has reached the potential E_0 measure this potential by changing switch to ON position and take reading on Voltmeter.
3. Vary V_{max} by choosing different θ_0 values and measure E_0 each time.
4. Plot a graph of E_0 versus V_{max} and observe it is linear.
5. Repeat after shifting the loads A, A (Fig.2.) so that T changes. The E_0 versus V_{max} data in this set-up fall on the same graph line as in step 4.

OBSERVATION TABLE 1

S.No	Release angle θ_0 (deg)	Capacitor Potential E_0 (Volts)	$V_{max} = P\frac{4\pi}{\cdot T}\sin\frac{1}{2}\theta_0$ (cm/sec)
1	50°		
2	45		
3	40		
4	35		
5	30		



`Fig.5. Ideal graph showing the variation of Induced emf with V_{max}

P=40 CM

$T = \frac{13.61}{5}$ sec

Part 2. To study the charge delivered due to electromagnetic induction

The induced emf E (eq.1) is applied in a circuit of resistance R the charge delivered is given by

$$q = \int_1^2 \frac{E}{R} dt = -\frac{1}{2}\int_1^2 \frac{d\Phi}{dt} dt = -\frac{1}{R}(\Phi_1 - \Phi_2) \quad \text{......................} (4)$$

When the diode in the circuit of Fig.6 the capacitor C integrates one pulse of Fig.3 and does not receive the opposite pulse. The charge collected is (1/R) times the $\int E\, dt$

PROCEDURE:-

1 Make the connections as Fig 6. keep RC large compared with width τ by connecting resistance R (given on the panel) in the circuit (Fig 3) which is approximately given by the magnet length divided by V_{max}. With a given release angle θ_0 measure V across the capacitor for N swings taking n=1, 2, 3… by turns. (Each time hold the D by hand after n swings are completed and measure V)

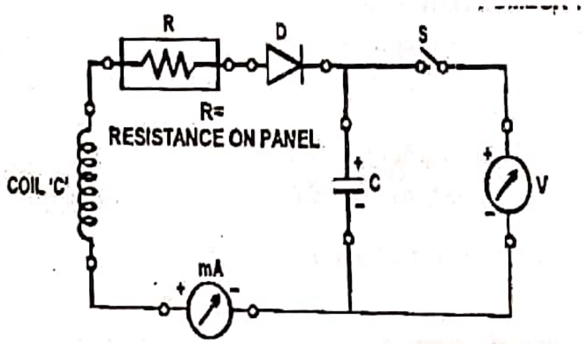


Fig. 6. Circuit Diagram for measuring Charge

2 Plot q=CV against number of swings (n). Observe the plot to be a straight line as shown in Fig 7.

3 Repeat with a different R values and observe the new q versus n curves.

OBSERVATION TABLE 2

Capacitance (C) in circuit = .10^{7}F...

Release angle θ_0 (deg) = .50.....

S.No	R₁ (...)			R₂ (...)		
	Swing 'n'	V (...) (Volts)	Charge Q=CV	Swing 'n'	V (...) (Volts)	Charge Q=CV
1						
2						
3						
4						
5						
6						
7						

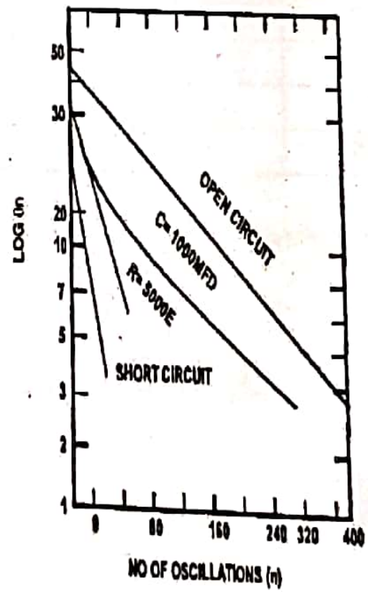


Fig.7. Graph showing the variation of Induced charge with no. of oscillations

RESULT

To be interpreted by the student basing on the observed data.

VIVA VOCE

2. What is electromagnetic induction?
3. State Faraday's laws of electromagnetic induction.
4. Why Michael Faraday is called the father of electricity though he was not the one who discovered electricity?
5. What is damping?
6. What are eddy currents?
7. State Lenz law.

APPLICATIONS

1. The ground fault interrupter (gfi) is an interesting safety device that protects users of electrical appliances against electric shock. its operation makes use of faraday's law.
2. Another interesting application of faraday's law is the production of sound in an electric guitar.
3. Generators and motors.