EXPERIMENT – 11

Aim of the experiment: To verify the Faraday's laws of electromagnetic induction.

Apparatus required: air core coils 10000 turns; bar magnets; D-shaped magnet cradle with stand, pointer & scale, adjustable brass masses; a box containing resistors, diodes, capacitors, switches, voltmeter and milliammeter.

Principle: Any conductor subject to a changing magnetic field produces an emf that is proportional to the rate of change of magnetic flux linked with the conductor. The direction of the induced emf is such as to oppose the cause itself. It is in conformity to the Lenz's law.

Faraday's law in its simplified form $e = -\frac{d\varphi_B}{dt}$

The emf induced across the ends of a coil is proportional to the rate of change of magnetic flux linked with the coil. Flux is a function of magnetic field and area of the coil.

The idea is to put a bar magnet on a non-magnetic swing (mechanical oscillator) such that the magnet rapidly passes through a multi-turn coil inducing emf across its ends. The profile of the induced emf closely resembles the waveform shown in fig-1. In order to observe the proportionality of emf and rate of change of flux the voltage of the waveform must be proportional to the velocity of the magnet through the coil. If the 'D' is released at an angle θ_0, from the equilibrium position, the maximum velocity v_{max}, of bar magnet placed on it that passes through the coil is given by,

$$v_{max} = \frac{4\pi R}{T} sin\left(\frac{\theta_0}{2}\right)$$

where,
R is the radius of the arc of the D shaped aluminum frame and,
T is the time period of oscillations.

A circuit diagram shown in fig-2, will aid in the determination of voltage induced in the coil due to the magnet threading it. The induced voltage is bidirectional as shown in fig-3, and cannot be measured using a dc voltmeter. Hence, a rectifier diode is employed to make the voltage essentially unidirectional. Now the output of the rectifier is a train of unidirectional pulses that gradually diminish in size with oscillations of the magnet getting damped due to friction and air drag. The pulsed dc output of the diode is then fed to a capacitor where the charges get stored and the capacitor voltage rises proportionately. A milliammeter is connected in the loop to get an indication of charging current through the capacitor, that is seen as a unidirectional jerk in its pointer. Once the charging is complete, the jerk loses its vigour after which a voltmeter is connected right across the capacitor to measure its voltage. This voltage should be proportional to the rate at which the magnet passes through the coil. Here the rate of change of magnetic flux is proportional to the speed with which the magnet passes through the coil and the voltage stored on the capacitor is proportional to the voltage induced.

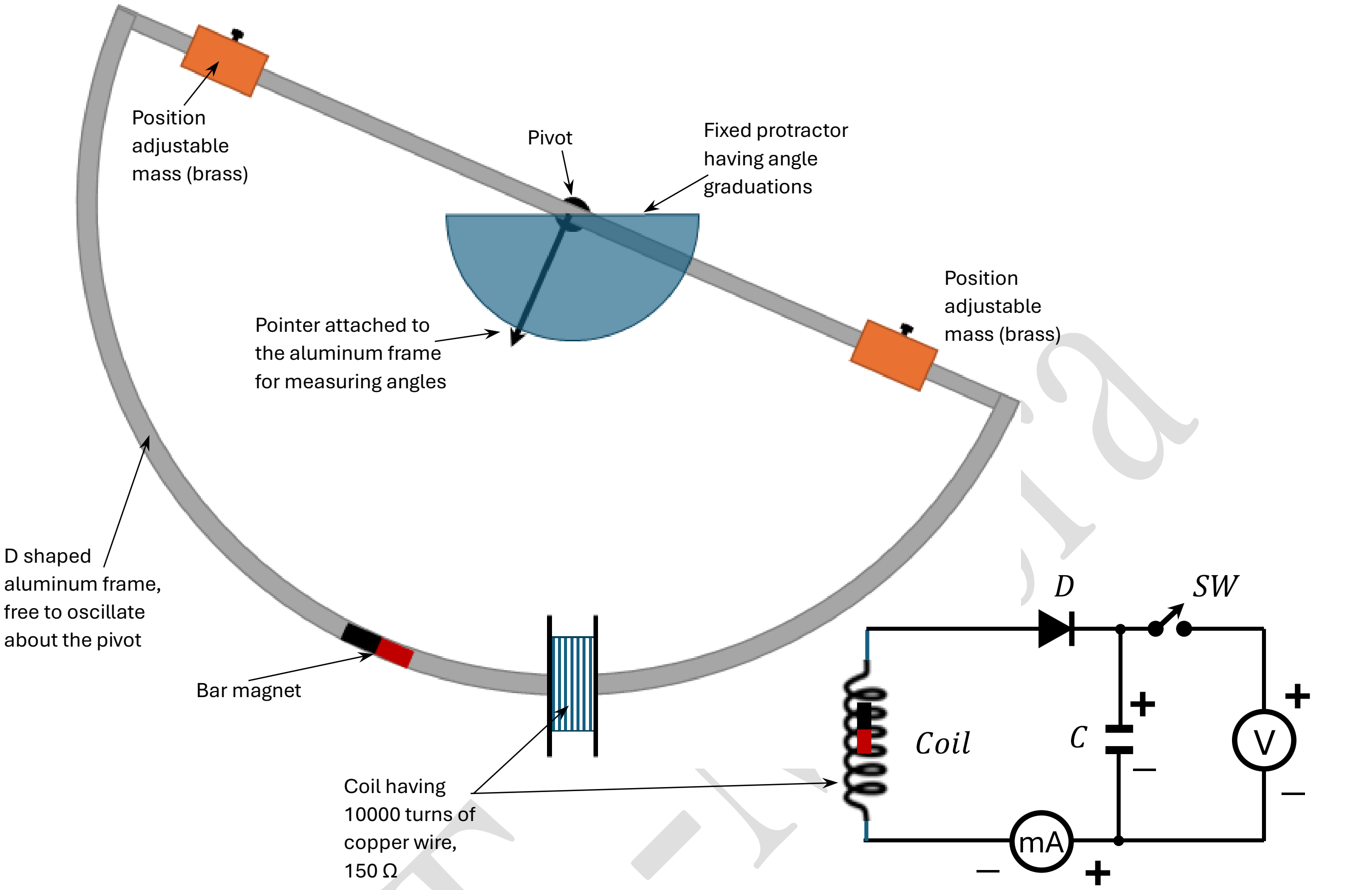

Fig-1: Schematic diagram of the setup used for the verification of Faraday's law of electromagnetic induction using a magnet threading a coil at different time rates

Fig-2: Circuit diagram for the determination of voltage induced in the coil due to the magnet passing through it.

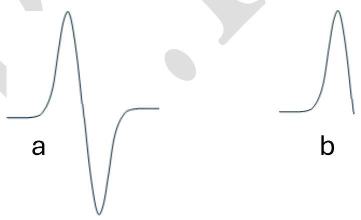

Fig-3:

a. Profile of the voltage induced in the coil due to the magnet passing through it.

b. induced voltage after rectification by the diode.

Procedure and precautions:

1. Make the connections as per the circuit diagram shown in fig-2.
2. Measure the radius of the frame and note it down.
3. Fix the bar magnet centrally on the D of the aluminum frame with the help of some bits of paper.
4. Adjust the two brass masses on the frame so that the pointer is at 0 deg. These masses can be brought closer to each other in order to decrease the time period of oscillations of the frame carrying the magnet.
5. Let the frame oscillate a little and ensure that it doesn't touch the former of the coil while in motion as that may impede its motion.
6. Once all settings are done, push the switch, SW towards OFF.
7. Push the frame through a desired angle and hold it with one hand. Hold a stopwatch in the other hand.
8. Release and allow the frame to freely oscillate and simultaneously start the stopwatch.
9. Record the initial angular amplitude and time period of oscillations on the observation table.
10. Use the voltmeter to measure the corresponding induced voltage in the coil, by flipping the switch SW to ON.
11. Record all the relevant data, complete the observation table and plot a graph of induced voltage against maximum velocity of magnet.

Observations & Calculations:

Recording the time period

$R =$ ________ cm

Table-1:

S.No.	Amplitude θ_0	Time period of oscillations T	Maximum velocity of magnet $v_{max} = \frac{4\pi R}{T} sin\left(\frac{\theta_0}{2}\right)$	Measured induced voltage e_0
	(deg)	(s)	(cm/s)	(V)
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				

Plot:

A plot showing the proportionality between induced voltage and the maximum velocity of magnet is to be drawn. If the data point do not lie on a straight line do not connect them point-to-point by separate line segments, rather draw a best-fit line through them.

Results and discussion:

Include your comments on the results obtained, the scatter or deviation in the expected proportionality. Try to reason out the important features observed by you.