National Anveshika Experimental Skill Test -2021

(NAEST – 2021)

Name:...Class....................................

Roll NO................................Mobile No..

School/College Name...

Date..Time...

F3- Emf due to a magnet falling in a solenoid

Background

If a magnet is made to fall through a solenoid, an emf is induced in it. The emf is given by

$$\varepsilon = -\frac{d\Phi}{dt}$$

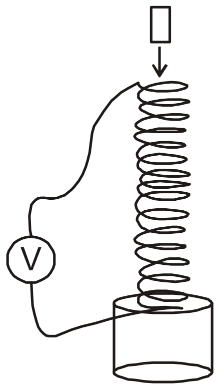

Figure-1

where $\Phi = \int \mathbf{B} \cdot \mathbf{da}$ is the total magnetic flux through all the turns of the solenoid. As the flux changes due to displacement of this magnet, the rate of change of flux and hence the emf is proportional to the speed of the magnet. In this experiment, you will hold a solenoid in vertical position, make the magnet fall from various heights and store the data on emf versus time using a computer interface, called ExpEyes. The data will be then analyzed to find the value of the magnetic flux when the magnet is at the centre of the solenoid.

EXPEYES

This is an interface between the actual physical experiments and a computer.

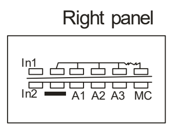

Figure-2

You will see two sets of buttons on the panel of expeyes. You will be using the set on the right. If you press a button, you can insert a wire in the hole above it. As you release the button, the wire gets fixed. On the upper line, you have four black buttons. These are connected to each other and connected to ground. You will also use button A1 on the lower line. The ground and A1 can be used as the two terminals of a voltmeter.

Expeyes is connected to the computer through a USB cable. A software is already installed on the computer. You run the software to get a window in which you can make many measurements. This window works as an oscilloscope. You see a grid on the left in which the y-axis is in volts and the x-axis is in time. You will see check boxes A1, A2, A3 on the right lower half of the screen. Put Check mark on A1.

You can set the range of voltage from a panel given on right upper half of the screen. Check the box A1 and set it at a desired volt by clicking on the range box and selecting. The initial range is 4V by default.

Materials

A solenoid, a stand to fix the solenoid, a set of cylindrical magnets, a transparent tube, connecting wires, expeyes interface.

Experiment

Preparation

Fix the given solenoid in the stand provided. Make sure that the axis of the solenoid is vertical. A cylindrical tube made with a transparent sheet is provided to you that push fits in the solenoid. Insert this tube in the solenoid with some height h above the top edge of the solenoid. If you release the magnet from the top of the tube, you can measure the height from the solenoid from where the magnet is released. Also the tube helps you to drop the magnet along the axis of the solenoid.

Connect the two ends of the solenoid to the ExpEyes interface (A1 and ground). Connect the ExpEyes to the computer and open the page. In case of difficulty, consult your evaluator teacher.

For trial, drop the magnet to go through the solenoid and check that you get a signal on the computer screen. It should be like that shown in Figure-3. Look at the scales on the plot. The vertical axis is for emf measured in volt and the horizontal axis is for time measured in second. Find out how much is one vertical division and how much is one horizontal division. Now you are ready to start the experiment.

At the beginning of this graph, the emf is zero, this is when the magnet is far away from the solenoid so that the magnetic flux Φ through the solenoid is negligible. Even if it is moved little bit, the flux remains negligible and hence there is no significant change in the flux. Thus the emf ε shown is almost zero. When the magnet reaches near the middle region of the solenoid, again a small movement does not change the flux significantly and so the emf becomes almost zero. This explains the first peak in the graph. Similar is the story with the second half as the magnet goes out of the solenoid.

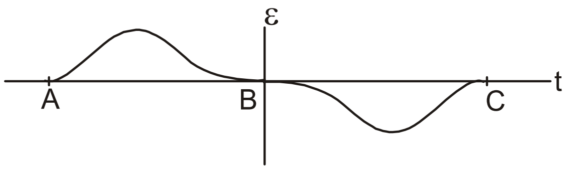

Figure-3

Part-1 : Recording the data

Drop the magnet from a measured height h above the top edge of the solenoid. Ensure that the axis of the magnet coincides with the axis of the solenoid while dropping. The screen will show emf versus time graph.

Take a graph sheet and draw horizontal and vertical axes on it. Hold the graph sheet on the screen. Adjust so that the time axis on the graph coincides

with the time axis on the screen. While holding the sheet carefully trace the emf-time curve on the graph sheet. Find different parameters of the curve, such as heights of the peaks, widths of the peaks etc.
Do it at least 3 times for the same height h and record your observations.
Repeat the experiment for a much longer height. Write your data for both heights in a tabular form. Include the heights h of dropping the magnet, height ε_1 of the left peak, height ε_2 of the second peak, time when the left peak is of maximum magnitude, time when the right peak is of maximum magnitude etc.

Part-2 : Getting the magnetic flux

Look at the shape of emf ε_1 versus t graph in Figure-3 again.

$$\varepsilon = -\frac{d\Phi}{dt}$$

So, $$\int_1^2 \varepsilon dt = -\int_1^2 d\Phi$$

Or $$\left|\int_1^2 \varepsilon dt\right| = \left|\Phi_2 - \Phi_1\right|$$

Thus the area under the peak from time t_1 to t_2 gives the net change in the flux in this time interval.
By counting the small squares, find the area under the left peak and under the right peak for the two heights of dropping. Take care of the squares which are partially inside and partially outside the curve. Convert in proper units of volt and second. Thus find the change in flux $\Delta\phi_1$ as the magnet crosses the portion of the solenoid corresponding to the first peak, and change in flux $\Delta\phi_2$ as the magnet crosses the portion of the solenoid corresponding to the second peak.

What is the flux when the magnet is in the central region of the solenoid.