

## Exercise 6: Lenz's law of electromagnetic induction

Purpose: to determine the direction of the induced emf and current in a closed circuit loop from a time changing magnetic flux.

### Introduction

Magnetic flux is the amount of magnetic field vector passing through a given area. Faraday's Law states that a time changing magnetic flux through an area bounded by a closed circuit induces an emf that drives the flow of current around the circuit. Lenz's Law gives a quick reference to the direction of the emf in a circuit loop as explained more completely explained by Faraday's law. Lenz's law states that the polarity of the induced emf produces a current that creates a magnetic flux which opposes the external change in magnetic flux.

We can see the direction of the current induced in a solenoid from a time changing magnetic field by observing the needle of a galvanometer. A galvanometer reads a positive current when the current enters the positive (+) input terminal and leaves through the negative (-) terminal. It reads a negative current when the current enters the negative (-) terminal and leaves the positive (+) terminal.

The magnetic field lines external to a bar magnet go from the N pole to the S pole. Since magnetic field lines are continuous, that is, they do not start or end anywhere, the field lines inside the bar magnet must necessarily go from the S pole to the N pole. This situation is in contrast to electric field lines, which do begin and end at electric poles (at positive and negative charges). All the magnetic field lines outside the magnet must be squeezed together as they pass through inside, going the opposite direction. If this is confusing, draw a simple diagram of a bar magnet, and add field lines to your drawing both inside and outside the magnet, indicating the directions of the fields with arrows.

### Laboratory assignment

1. Connect the galvanometer to the solenoid. Note how the coil wraps and how it is connected to the galvanometer.
2. First, move the bar magnet in and out one end of the solenoid to see if the meter responds. If the galvanometer does not respond, then ask your instructor for help.
3. Starting with the magnet far from the galvanometer, push the bar magnet, leading with the south pole, from the left and toward the solenoid until it is partial inside. Perform this task with a fair amount of speed to observe a large signal.
4. [Draw an illustration of your method in step 3](#), similar to Fig. 1 including (i) solenoid winding direction, (ii) bar magnet orientation, (iii) direction of bar magnet velocity, (iv) direction of current in wire, and (v) galvanometer needle direction. An example illustration is shown in Fig. 1.

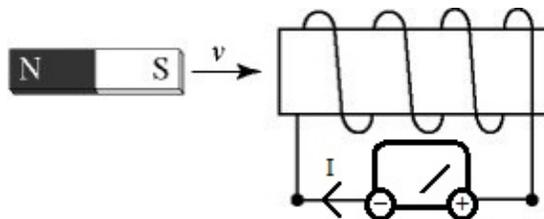


Fig. 1: A diagram depicting a situation in the Lenz's law laboratory.

5. Starting with the magnet far from the galvanometer, push the bar magnet, leading with the north pole, from the left and toward the solenoid until it is partial inside.
6. [Draw an illustration of your method in step 5.](#)
7. Starting with the magnet far from the galvanometer, push the bar magnet, leading with the south pole, from the right and toward the solenoid until it is partial inside.
8. [Draw an illustration of your method in step 7.](#)
9. Starting with the magnet partially inside the left side of the solenoid with the north pole being inside the solenoid and south pole being outside the solenoid, pull the bar magnet to the left until it is away from the solenoid.
10. [Draw an illustration of your method in step 9.](#)
11. Starting with the magnet partially inside the right side of the solenoid with the south pole being inside the solenoid and north pole being outside the solenoid, pull the bar magnet to the right until it is away from the solenoid.
12. [Draw an illustration of your method in step 11.](#)
13. Perform one of the experiments above and vary the speed of the magnet. [What effect does varying the speed with which you insert or remove the magnet from the solenoid have on the induced emf in the solenoid? Explain your observations using Faraday's Law.](#)
14. [Under what conditions does a current flow in response to a magnetic field?](#) For instance, how about when the magnet is at rest in the solenoid? [Explain in detail.](#)
15. Perform another set of experiments to answer the following questions. [Can you cause a current to flow in the solenoid by moving the bar magnet along the outside of the solenoid rather than inside the solenoid? If so, are certain orientations of the magnet more effective than others for inducing this current? Observe and explain.](#)

*Equipment list: bar magnet, solenoid, banana cords, galvanometer.*