Group Members: Pearl O, Emilie E, Neptune B, Cyrus X, Cindy T, Jasmine G, David Fu, ismail A, mackenzie chia, arrsh b, marc m. russell yang

LAB: Lenz's and Faraday's Laws

Driving Question | Objective

This lab will test the factors influencing Lenz's and Faraday's laws, such as the direction of current and the size of induced emf (changing magnetic flux).

Materials and Equipment

- Alligator Clips
- Compass
- Modular Circuits
- Batteries
- PASCO Capstone Software
- Switch
- Wire Coil (& 200, 400, 600 count)
- Disk Magnets (2 different strengths)
- Voltmeter
- Sheets of Paper
- Resistor (100 ohm)

Background

Lenz's law was discovered in 1834 by Russian physicist Heinrich Lenz, who showed how thrustring a bar magnet through a coil wire induces current in the wire. Lenz's law determines the direction of the current. Faraday's law, discovered by Michael Faraday, builds on observations by Lenz. Faraday visualized a magnetic field of many lines of induction, with interesting lines called magnetic flux. Changing magnetic flux is associated with an induced emf (electromotive force). Faraday's law determines the size of the induced emf.

$$\varepsilon = -N\frac{\Delta\Phi}{\Delta t}, \quad \Phi = BA\cos\theta$$

(N = number of loops, B = magnetic field, A= area, ε = induced voltage)

In this lab, focus should be given to the direction the compass points, and magnetic south/north pole vs. compass direction should be considered, as compasses may have reversed polarity. Special attention should also be given to the pole of the magnet entering the coil first in Faraday's law. In Lenz's law, parameters such as initial height, number of coils, and magnet strength should be considered with all other factors held constant.

Safety

- In this lab, make sure to be careful when catching the magnets after they are dropped through the coils. The higher the initial position, the greater the final velocity as it hits one's hand.
- Handle all electrical equipment with caution.

Procedure

Part 1: Magnetic Field Direction

1. Build the circuit shown in the image A below (keep an eye on the placement of the battery to see which direction the positive and negative ends of the battery are facing in relation to the rest of the circuit)
2. Place the compass at point one (image B)
3. Record the magnetic direction the compass points in Data Table 1 (Remember that cardinal north is magnetic south and vice versa)
4. Repeat steps 2-3, to record the magnetic directions the compass points in points 2-4 (image B).
5. Once that is completed, turn the batteries in the opposite direction (image C) in the circuit.
6. Place the compass at point one (image B)
7. Record the magnetic direction the compass points in Data Table 2
8. Repeat steps 6-7 for points 2-4 in the circuit. Measure and record the magnetic direction in Data Table 2.
9. Once that has been completed, connect all the disk magnets together, and leave the circuit to the side.
10. Place the bar magnet in the position (image D)
11. Hold the compass to each end of the bar magnet and note which side is the north and the south magnetic pole to make sure your data is recorded accurately.
12. Place the compass at point 1 (image D)
13. Record the magnetic direction the compass points towards in Data Table 3
14. Repeat steps 12-13 for points 2-4, (image D)

Image A

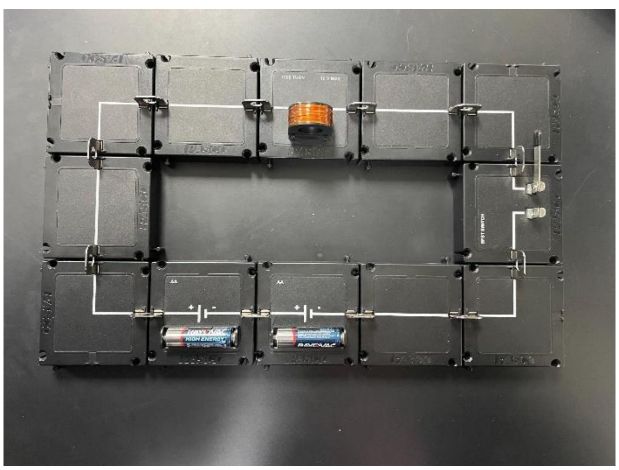


Image B

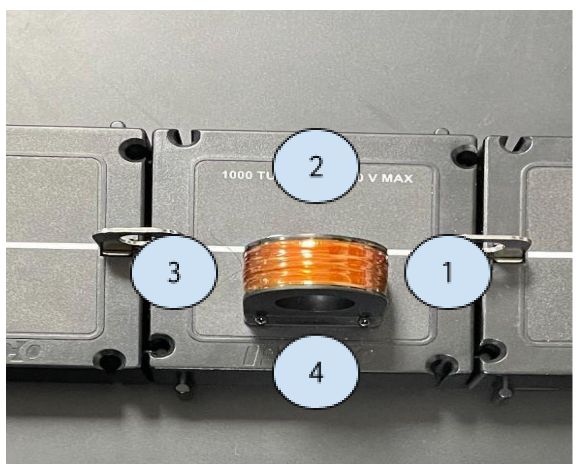
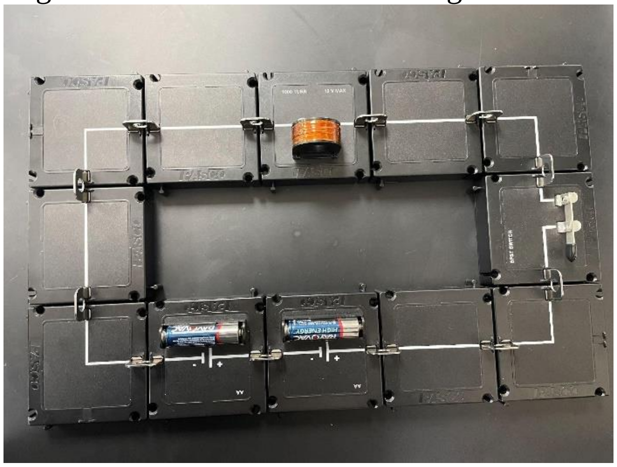
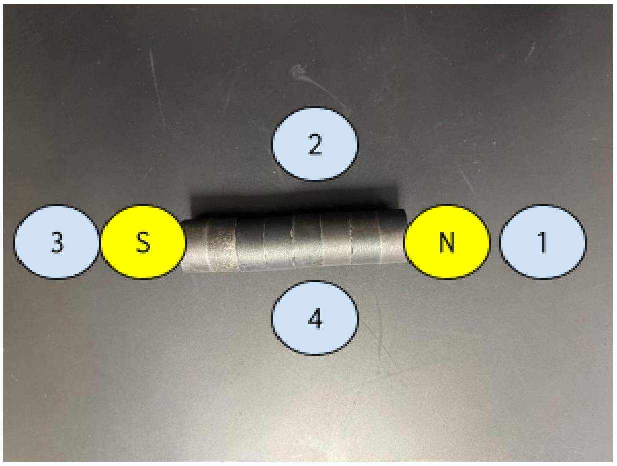


Image C Image D





Part 2: Magnetic Field Strength

1. Build (or bring back) the circuit (Image A). The positive end of the battery should be facing away from the switch with the negative end towards it.
2. Leave the switch open.
3. Place one disk magnet inside the coil, sitting up on the rounded end, as shown in Image B, which will be denoted as "Position 1"
4. Once the magnet has been placed in the coil, close the switch and observe, and record, its final state in Data Table 1.
5. Repeat steps 2-4 for positions 2-4, which are represented in Images C,D, and E.(not necessary to follow the magnet pole directions- just make sure all positions are tested)
6. Remove one battery from the circuit and replace it with a 100 ohm resistor (Image F)
7. Repeat steps 2-4 for the same four positions (Images B-E) and record the final state in Data Table 2 below

Image A

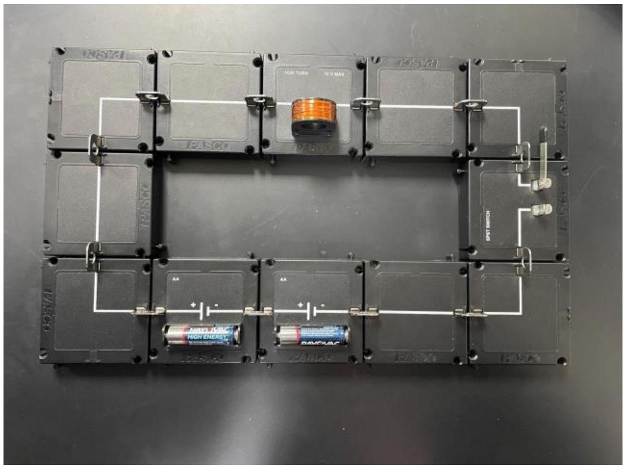


Image B-Position 1

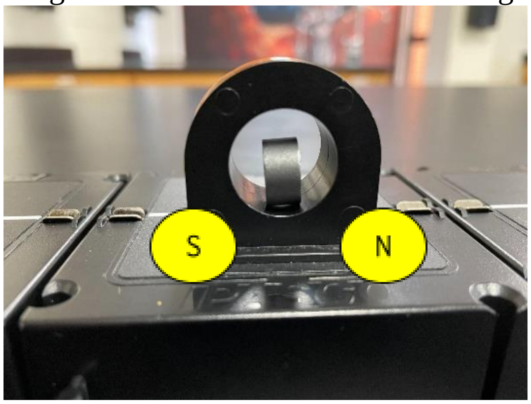


Image C-Position 2

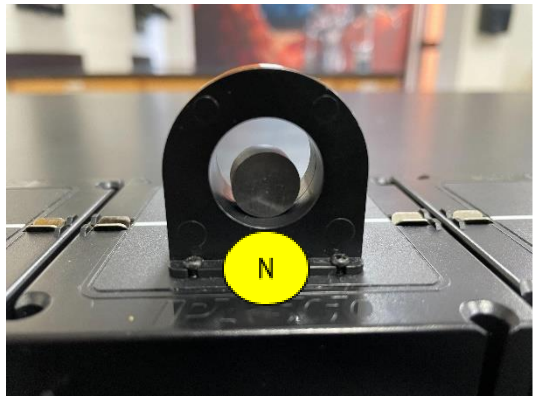


Image D-Position 3

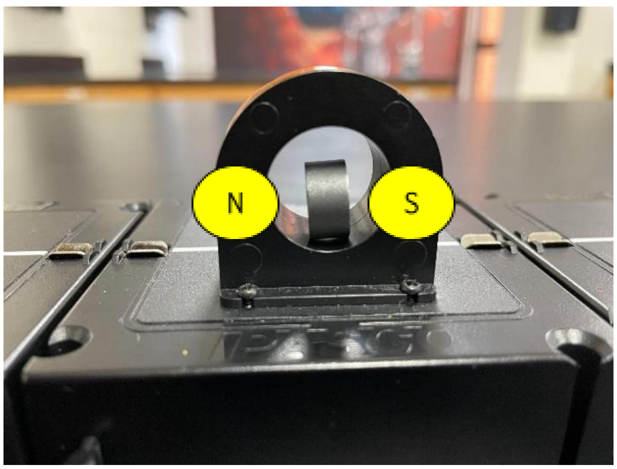


Image E-Position 4

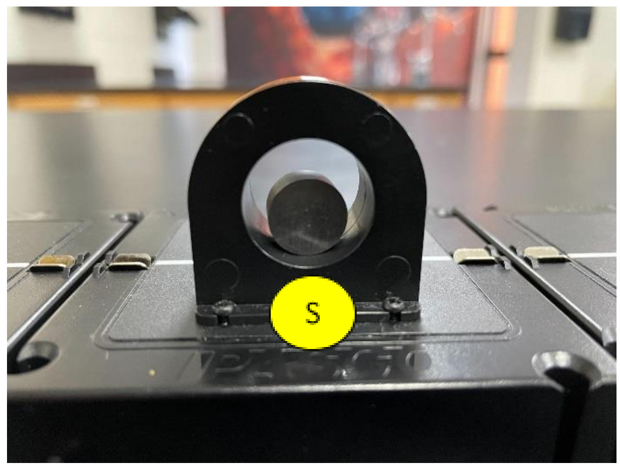
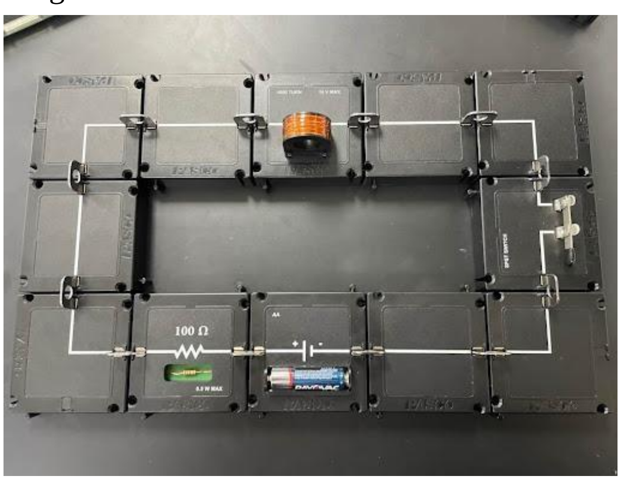


Image F



Part 3: Voltage change

<u>Height</u>

1. Obtain the 200 coil count. Open the PASCO software and the induction file. Attach the red wire on the top connector and the black wire on the bottom connector of the coil.
2. Place the coil count on a steady surface at a decent height above the table, and make sure the hole is not covered. Place the longest yellow paper cylinder through the hole. (Image B)
3. Obtain the weak (gray) magnets and arrange the disks into one large cylindrical magnet.
4. Have another person (besides the one who is holding the coil) place one hand on the table to catch the magnet and the other hand above to drop the magnet through the yellow paper.
5. Have another person record the voltage change on PASCO as the magnet drops. Note the voltage pattern when the magnet enters and leaves the yellow paper in Table 1.
6. Swap the longest yellow paper for the medium length one, and repeat steps 2-5. Then, repeat with the smallest length paper.

<u>Coil Count</u>

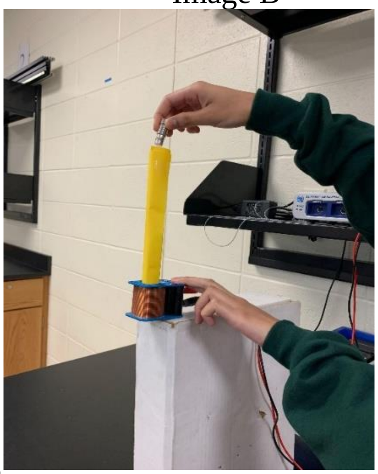
1. Copy the weak magnet voltage recordings for medium height (Table 1) into Table 2 for the "200 coil" row (these are the same measurements).
2. Attach the voltage sensor wires to the 400 coil count, use the medium length yellow paper, and drop the weak magnet through in the same way the "Height" experiment was conducted.
3. Record voltage observations in Table 2.
4. Repeat steps 2-3 with the 800 coil count.

<u>Magnetic Strength</u>

1. Obtain the 200 coil count and set up the experiment in the same way the previous experiments have been set up with the coils. Use the medium length yellow paper.
2. Transfer the same measurement in Table 1 for the voltage with the medium height paper under "weak magnet voltage" to Table 3.
3. This time, use the strong silver disk magnets and link them in one large magnet.
4. Drop the strong magnet through the paper while recording the voltage pattern and catch the magnet before it hits the table.
5. Record the voltage pattern in Table 3.

Image A

Image B



Data Analysis

PART 1

Data Table 1-Coil and Batteries (Negative End to Switch)

Position of Compass	Magnetic Direction
Point 1	W
Point 2	E
Point 3	W
Point 4	E

Data Table 2-Coil and Batteries (Positive End to Switch)

Position of Compass	Magnetic Direction
Point 1	E
Point 2	W
Point 3	E
Point 4	W

Data Table 3-Magnets

Position of Compass	Magnetic Direction
Point 1	S
Point 2	N
Point 3	S
Point 4	N

PART 2

Data Table 1- 2 Batteries

Position	Final State (What is the final position of the magnet, state A and B as outlined in the images above) + speed
1	Final position is parallel to the loop, spun fast
2	Final position is parallel, spun fast
3	
4	

Data Table 2- 100 Ohm Resistor and 1 Battery

Position	Final State + speed
1	
2	
3	
4	

PART 3

Table 1- Varied heights

	Weak magnet Voltage (in, out)
Long height	0.243, -0.260
Medium height	0.241, -0.192
Short height	0.183, -0.140

Table 2- Varied coil counts

	Weak magnet Voltage (in, out)
200 coil	0.241, -0.192
400 coil	0.416, -0.477
800 coil	0.944, -1.066

Table 3- Varied magnetic strengths

	Weak magnet Voltage (in, out)	Strong magnet Voltage (in, out)
Medium height	0.032, -0.028	0.241, -0.192

Analysis Questions

This is where your group should create 4-5 open ended, thought-provoking questions on concepts student have taken from conducting the lab. These questions should help them prepare for the lab quiz that your group has prepared for them. However, the questions here should not be identical to the ones in the quiz.

1. By rotating the batteries in part 1, what change occurs in the circuits and how does that impact the magnetic field?

The direction of current switches directions in the circuits. This impacts the magnetic field by switching the direction of the magnetic field as well.

2. How does the magnet respond when current is flowing through the coil in part 2? Describe similarities or differences when you rotated the magnet 90 degrees after each trial.

Part 2 omitted.

3. How does the magnet respond when you replace a battery with the resistor in part 2 (effect on current)? Why?

Part 2 omitted.

4. In part 3, how do the voltages when the magnet moves into and out of the coil compare?

The voltages are higher when the magnet moves out of the magnet than when it moves into it.

5. In part 3, determine the flux by measuring the area under the voltage versus time curve for the medium length, 200 coil count, weak magnet data. Is the incoming flux significantly greater, less, or about the same as the outgoing flux? Why?

The outgoing flux is greater, but not too significantly. This increase in flux is because the magnet is moving at a faster speed when it is going out because of the acceleration due to gravity.