Calculus Based Physics 1: LAB

PHYS 2110 WA

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Experiment 7: Electromagnetic Induction

Groups:

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**Objective:**

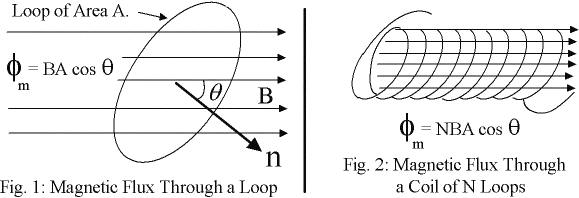
The objective of this lab is to qualitatively examine **Faraday’s Law** of Electro-magnetic Induction

**Equipment:**

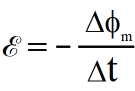
A computer with internet connection, paper, pencil, calculator (ti-84 plus CE, ti-30sx II)

**Theory:**

**Electromagnetic induction** takes place when a current is generated in a coil of wire due to a change in magnetic flux through its loops. The **Magnetic flux, φm** of field **B** through a **wire loop** of area **A** is given by **φm = BAcosϴ** where **ϴ** is the angle that B makes with normal to the area, **N**, as shown in the figure in the lab manual. For a coil of N loops, Magnetic flux is equal to the area for N loops. This is shown as **φ = NBAcosϴ.**

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If any combination of N, B, A, or ϴ changes with time, then it will induce an electromotive-force (emf) E across the coil that is equal to the rate of change in Flux over the change in time.



E stands for “electro-motive force (emf)” or simply voltage, V. We can then rewrite it as:

V = -Δφ/Δt instead.

The negative sign (-) indicates that the induced voltage V and the change of flux have opposite signs.

**Procedure:**

After opening up the laboratory software, the magnet included in the lab was set to include the field lines, and other settings included were tested before the cases were conducted. Observed at the beginning of the lab was the neutral zone of both a 2 coil loop and a 4 coil loop, which was connected to a galvanometer.

The magnetic bar was configured to show field lines and with the north pole of the magnet to face both of the coils, then the cases provided in the lab manual were followed.

The magnet bar was then pushed in and out of both coil loops at very speeds. The galvanometer was observed as the bar was pushed. This was done to confirm that the needle did not fluctuate past the 22.5° mark when the magnet was pushed slowly, and 45° when the magnet was pushed at a moderate speed. After the angle of deviation was recorded, the deviation of whether the needle had gone positive or negative was also observed and recorded.

After all observations were recorded, the same cases were repeated, but with the magnet configured to have the south pole to face both coils. Then the previous cases were followed, with each case done at a varying speed, and then observing the deviation of angle and charge.

All of the observed results were then elaborated on further in the conclusion section of the report.

**Data:**

**Given: N/A**

**Measured:** Relative Position of the ammeter or voltmeter

|  |  |  |
| --- | --- | --- |
| **Magnetic Induction Chart** | Magnetic Polarity:  **N --------- S** | Magnetic Polarity:  **S ------- N** |

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Coil Size** | **Speed** | **Direction** | **Ammeter**  **Deviation**  **(Degrees)** | **Deviation**  **(+) or (-)** | **Ammeter Deviation**  **(Degrees)** | **Deviation**  **(+) or (-)** |
| **2 Loop Coil** | **Slow**  **Slow**  **Moderate**  **Moderate** | **In**  **Out**  **In**  **Out** | ~22.5°  >12°  >45°  ~45° | (+)  (-)  (+)  (-) | >22.5°  >22.5°  >45°  >45° | (-)  (+)  (-)  (+) |
| **4 Loop Coil** | **Slow**  **Slow**  **Moderate**  **Moderate** | **In**  **Out**  **In**  **Out** | <22.5°  >22.5°  <45°  >45° | (+)  (-)  (+)  (-) | >22.5°  >22.5°  >45°  >45° | (+)  (-)  (+)  (-) |

**Calculations**

While no calculations were needed during the procedure of the lab, there is a mathematical analysis of Faraday’s Law of magnetic induction.

The basis of Faraday's law is that a change in the magnetic field will cause change in the induced current, mathematically we can use E (or V) = -N Δφ/Δt, which essentially means that to get an electromotive force (emf), then there has to be a change in the magnetic field over time.

This means that if the time to change the magnetic flux is short, then the emf will be greater, but if the time to change the magnetic flux is longer, then the change in emf will not be as great.

This means that in order to manipulate the emf/V, you can adjust the magnetic flux φ, or “phi”. This can be done in three ways:

Through the area, the angle, or the magnetic field. Given as: **φm = BAcosϴ**

B is the magnetic field itself, measured in Tesla. The way that you can induce change in magnetic flux and cause emf is to change the magnetic field itself. This can be done by pushing a magnet through the magnetic field lines, this will increase B, and cause an emf. If the magnet is not moved at all and is stationary, then there can be no change in B and no emf.

A is the area. If the area is increased, then the magnetic field will also increase, which will then cause an induced flux, emf.

The reason for the use of *cosine* is because the angle is measured is between the normal line and perpendicular to the face of the coil and the magnetic field. As the angle approaches 1, then the maximum possible maximum flux is possible. Inversely as the angle approaches 0, then the magnetic flux decreases.

**Comparison of the results:**

N/A

**Conclusion:**

The objective of this experiment was the qualitatively examine Faraday’s Law of Electro-magnetic Induction. The observations made to the reaction of a Galvanometer when a magnet is pushed in and out of a coil shows that with an increase of velocity **V** into a magnetic field **B**, then there will be a force F perpendicular to the magnet.

It was observed that at different speeds tested, then the galvanometer would fluctuate much further from the center point, this is because Faraday’s law states: E = Δφ/Δt. Which indicates that the emf is dependent on *rate of change in magnetic flux*. Meaning the greater the speeds, the greater the emf.

Two observations were made during the procedure of the lab, both were explained below:

The first observation was made during the experiment, particularly when placing a bar magnet inside the neutral zone of the 3 lop coil, when moving the coil as far up and as far down as possible, the galvanometer would spike and fluctuate all the way to the positive side to 0°, then go back to the neutral reading. When returning to the neutral zone, the needle would spike all the way to the negative side of the meter, then back to neutral.

The second observation was made when rapidly flipping the polarity of the magnet. This causes the meter to spike very rapidly from positive to negative until stopping and resting the magnet in one position, where it then returns to neutral.

This can be explained by ***Lenz’s Law.*** *The direction of the induced current in a coil is such that the magnetized coil opposes the motion of the external magnet that causes it.* When the N-Pole of magnet is pushed towards either the 2 loop coil or the 4 loop coil, then the current at the ends of the coil that is closest to N will become attracted and become an N pole, which tries to oppose the N-pole approaching. Then when trying to pull the magnet out of the coil, the closest side of the coil to the N pole that is leaving will become S and try to oppose the coil leaving. This law is the same inversely when we push the S-Pole of the magnet near the coils. The closest coil when pushing the bar becomes magnetized and S-Pole, then the closest coil when pulling away becomes N-Pole.

An explanation for observation one is the same as when we push the magnet horizontally inside of the coil. When we push the magnet all the way up or down vertically, we are essentially recreating the initial experiment of pushing the magnet close to the coil. This causes the nearest part of the copper coil to magnetize and become a N-Pole to oppose the magnet, then when we pull the magnet far enough away and towards the neutral zone, it will become an S-Pole and oppose the movement. Then when the magnet is back to the neutral zone, the magnetic fields reach equilibrium and the galvanometer stabilizes and goes to neutral.

The second observation is essentially the same thing happening, just a more rapid rate since we are flipping the magnet constantly. When we start to spin the magnet, the coil around it magnetizes very rapidly. Due to Lenz’s law, the coil will always attempt to oppose the approaching magnet before changing to an S-Pole to oppose the leaving of a magnet. So when we rapidly flip the magnet we are rapidly flipping the magnetic field itself into a repelling and attracting state.

**Discussion:**

N/A

**Questions:**

In Faraday's formula:**V =-Δφm/Δt**,

**(1) Mathematically, what factor does show the effect of speed?**

The factor that shows the effect of speed is **-Δφm** the greater the magnitude of emf is because there is a greater speed that is effecting the magnetic field lines. This increase in speed causes a greater rate of change in the magnetic field, which effects emf.

**(2) How does the slow motion of a magnet into or out of a coil result in a small induced voltage?**

This is the same reason as question 1, just reverse, the slower a speed on a coil then the smaller change in flux in the rate of change of the magnetic field, which leads to a smaller result in emf.

**(3) How does the fast motion of a magnet into or out of a coil result in a greater induced voltage?**

The faster the motion in and out of the coil increases the flux in the magnetic field, so the rate of change increases. This means that that the resulting emf will be greater.