I. Cover Page

Lab Name and #: Electromagnetic Induction, Experiment #21

Name: Date: 21 March 2011

Section Number: PHYS 2212 D with lab 1114 D ID:

Partner Names:

Abstract:

 The purpose of the lab was to study the laws of electromagnetic induction, Lenz’s and Faraday’s Law, and the effect of iron on a magnetic circuit.

II. Background

 A wire carrying an electric current creates a magnetic field around the wire. If the wire is coiled into a spiral, called a solenoid, then the magnetic field resembles the magnetic field of a bar magnet. One of the ends of the solenoid will behave like the north (seeking) pole of a bar magnet, and the other end will behave like a south pole.

 Any change in the magnetic environment of a coil of wire will cause a voltage (emf) to be "induced" in the coil. Electro-Motive Force is an old name for the voltage created not by a battery but by a changing magnetic field. The emf can push electrons around in a conductor, much as the battery voltage can push electrons through a wire. No matter how the change is produced, the voltage will be generated. The change could be produced by changing the magnetic field strength, moving a magnet toward or away from the coil, moving the coil into or out of the magnetic field, rotating the coil relative to the magnet, etc. If the conducting path is a closed circuit, a current will flow. The magnitude of the current depends on the emf (voltage) and resistance of the circuit (remember Ohm's Law). The direction of the current is the same as the direction of the induced emf.

 Faraday’s Law of Induction for the emf induced in a conducting loop is emf = - N Δ / Δ t that is, the magnitude of the induced emf depends upon the number of turns of wire **N** in the loop and on the time rate of change of the magnetic flux, , which is the product of the magnetic field **B** and the area of the loop. The flux can change because the magnetic field is changing - **B** is increasing or decreasing; the area of the loop is changing - it is changing shape; or the orientation of the loop with respect to the magnetic field direction is changing.

 The direction of the induced emf is given by Lenz's Law. Lenz’s Law states whenever a current flows as a result of an induced emf, its direction is such as to establish a magnetic flux which opposes the change of conditions giving rise to the induced emf. The induced current tends to keep the flux through the loop constant.

Interesting Facts:

* Electromagnetic induction is the key phenomenon behind energy converting devices such as electric motors, generators, and transformers
* Electromagnetic induction is also used to produce electricity in electric generators. Here, an outside force is used to create current by moving a magnet, thus supplying a changing magnetic flux. For example, hydroelectric generators use the force of moving water to create large amounts of electromagnetically induced current.
* Induction cooking uses electromagnetic energy to heat cookware made of magnetic material (steel, iron, nickel or various alloys). When the unit is turned on, the coils produce a high frequency alternating magnetic field that ultimately flows through the cookware. Molecules in the cookware move rapidly back and forth, causing the cookware to become hot and cook the food.

III. Procedures

Part I:

1. We gathered the necessary equipment to perform the experiment. The equipment required is bar magnet, galvanometer, a switch, rheostat (0 – 40 ohm), DMM, primary and secondary coils with soft iron core, and 5 V power supply.

(a) Secondary Coil (b) Primary Coil (c) Soft Iron Core

2. We removed the inner (primary) coil from the outer and connected the outer coil (secondary) to the galvanometer. We thrust the north pole of the magnet into the center of the secondary and observed the magnitude and direction of the deflection of the galvanometer needle for a fast motion and also for a slow motion. Note: A deflection to the right means that the current entered the positive terminal of the galvanometer. We recorded our observation in the table provided.

Production of a Current by a Time-Varying Magnetic Field.

3. We repeated Step 2 by withdrawing the north pole of the magnet from the center of the coil.

4. We repeated Steps 2 and 3 by using the south pole of the magnet. Note: A plus sign indicates that the direction of the current through the galvanometer is from the left to right. A minus sign indicates the opposite in the table above.

5. We replaced the small coil (primary) inside the larger one and made the connections shown below. We had our instructor check the completed circuit prior to continuing.

Mutual Induction

6. We ensured the soft iron rod was in the center of the primary coil and the primary coil was in the center of the secondary coil. We adjusted the current in the primary to 0.2 ampere by using the rheostat. We observed the magnitude direction of the deflection when the primary circuit was opened and again when it was closed. We recorded our results.

7. With the soft iron rod in the center of the primary coil and the primary coil in the center of the secondary coil we repeated step 9 using the rheostat for 0.4, 0.6, 0.8 and 1.0 amperes. We observed the magnitude direction of the deflection for each circuit while it was opened and again when it was closed. We recorded our results.

8. With a primary current of 1 ampere, we observed the amount and direction of deflection of the galvanometer upon opening and closing the primary circuit:

* With the iron rod in place. We recorded our results.
* With a primary current of 1 ampere, we observed the amount and direction of deflection of the galvanometer upon opening and closing the primary circuit with the iron rod 1/3 of the way out. We recorded our results.
* With a primary current of 1 ampere, we observed the amount and direction of deflection of the galvanometer upon opening and closing the primary circuit with the iron rod 2/3 of the way out. We recorded our results.
* With a primary current of 1 ampere, we observed the amount and direction of deflection of the galvanometer upon opening and closing the primary circuit with the iron rod completely removed. We recorded our results.

9. We constructed a graph of Primary Current vs. Galvanometer Deflection using the data from Steps 6 and 7.

IV. Data

Recreated for report. Original attached.

Table 1. Qualitative Results for Procedures 2 - 4

|  |  |  |  |
| --- | --- | --- | --- |
|  | Direction of current | Galvanometer deflection (slow motion) | Galvanometer deflection (fast motion |
| North Pole into coil | **+** | 30 | 50 |
| North Pole out of coil | **-** | 40 | 50 |
| South Pole into coil | **-** | 30 | 50 |
| South Pole out of coil | **+** | 40 | 50 |

Table 2. Quantitative Results for Procedures 6 -7

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Primary Current (amperes) | Direction of secondary current (opening) | Direction of secondary current (closing) | Galvanometer deflection (opening) | Galvanometer deflection (closing) |
| 0.2 | **-** | **+** | 2 | 2 |
| 0.4 | **-** | **+** | 8 | 8 |
| 0.6 | **-** | **+** | 12 | 12 |
| 0.8 | **-** | **+** | 16 | 16 |
| 1.0 | **-** | **+** | 18 | 18 |

Table 3. Qualitative Results from Procedure 8

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Primary Current (amperes) | Direction of secondary current (opening) | Direction of secondary current (closing) | Galvanometer deflection (opening) | Galvanometer deflection (closing) | Magnetic circuit |
| 1.0 | **-** | **+** | 18 | 18 | Iron Core |
| 1.0 | **-** | **+** | 12 | 12 | 2/3 Iron core |
| 1.0 | **-** | **+** | 6 | 6 | 1/3 iron core |
| 1.0 | **-** | **+** | 0 | 0 | No iron core |

VI. Results

VII. Conclusions

VIII. Questions

1. In procedures 2-4, the change in direction of the current illustrates which law of physics?

2. In procedures 2-4, the change in magnitude of the galvanometer deflection as the speed of the motion is increased illustrates which law of physics?

3. In procedures 6-7, how does the increase in primary current affect the galvanometer deflection? This is a consequence of whose law?

4. The galvanometer deflection in procedure 8 gradually decreases as the iron core is withdrawn. How does Faraday’s Law account for this behavior?

Optional Question:

1. Is it possible to construct a DC transformer? Explain.

Exercise

1. The magnetic field perpendicular to a circular coil of 5 turns and diameter 20 cm changes from+1.85 T to -0.25 T in 30 ms. Find the change in magnetic flux and induced emf.