7.2: Activities

Equipment

- coil with magnet-on-pedestal
- compass
- large wire coil
- solenoid
- oscilloscope
- Pasco box with voltmeter connection wires
- laptop
- wires

The General Idea

The goal of this lab is to look at Faraday's law of induction and Lenz's law, qualitatively in the first part, and quantitatively in the second. In each case the source of the magnetic field is different – a permanent magnet is used in the first part, and a current-carrying coil in the second.

Part 1 – Moving a Coil Near a Permanent Magnet

You have at your disposal a small dowel pedestal (on top of which rests a magnet), and a plastic loop that contains two coils of wire (one red, one black). The magnetic field of the magnet is not uniform, so moving a coil near it should change the flux and induce an emf across the leads of the coil. The only restriction we have on "moving the coil near it" is to keep the coil threaded onto the plexiglass tube. Other than that, you should explore changes with as much variation as possible. At a minimum, you should try different speeds, different directions of motion, different wire connections, and both orientations of the coil. Here are some details you need to know to get this to work:

- The Pasco software on the laptop you will use is "Electromagnetic_Induction_1."
- The voltage sensor cable needs to be connected into port A of the Pasco box. These are the leads across which the induced emf is measured.
- The red and black wires are wound around the coil in the same direction, each with 25 turns. It is possible to experiment with only one color of wire (giving you a result with 25 turns), and then repeat it with both coils involved together in series (giving you a result with 50 turns).
- The voltage sensor wires are colored red and black. When the red lead is at higher potential than the black lead, then this shows up on the graph in the laptop above the axis.
- You have a compass at your disposal to determine which magnetic pole is facing up at the top of the pedestal (it's easiest to test by removing the plexiglass and turning the pedestal sideways). For reference, the Earth's northern pole is actually a *south* magnetic pole (field lines go *into* it).

Part 2 – Varying the Magnetic Field by Varying the Source Current

We couldn't do a lot of quantitative study in part 1, because we don't have a good way of determining the numerical value of the magnetic field flux as a function of time. In this part, we create a varying magnetic field ourselves through the use of a varying current in a loop. Here is some information about the equipment at your disposal:

- The Pasco software on the laptop you will use is "Electromagnetic_Induction_2."
- The large coil of wire has 100 turns in it, and has a radius of $15.7cm$.
- The cylindrical "probe" is a coil with 1000 turns, and it has a radius of $1.3cm$.
- After you click the "On" button, the software provides a periodic signal to the large coil from the $\equiv$, and $\sim$ jacks in the Pasco box. You can change the frequency from the default to whatever you want (within reason!). You should not make any changes to the default amplitude.
- The software displays (when you click the "Monitor" button) the output current in the graph on the right. You can use the coordinate tool to get greater precision for values on this graph.
- The oscilloscope is connected to the cylindrical probe, and measures the induced emf in that coil.
- Check to make sure that the oscilloscope settings are on the proper defaults, as they were the last time you used it:
    - In the TRIGGER section set the slide switches to...

- MODE: P-P AUTO
  - SOURCE: CH 1 and LINE
- All the smaller dials labeled "CAL" within the three largest dials (for voltage and time) should be turned fully clockwise.
- In the HORIZONTAL section, set the slide switch to X1.
- In the CH 1 part of the VERTICAL section set the slide switches to...
  - upper slide switch: CH 1
  - lower slide switch: DC

Some Things to Think About

Part 1

Here are some questions for you to consider when explaining how (or if) the behavior you observe is consistent with Faraday's and Lenz's laws.

- What seems to affect the peak emf that is measured?
- If you want to compare the results of one coil (say just red) to two coils (both red and black)...
  - ... how you will need to connect the leads?
  - ... how will you keep the speed variable unchanged between these two tests?
- How does the result of moving the loop upward compare to moving it down?
- What effect is there (if any) when you turn the loop over and repeat the procedure?
- If you move the coil at different speeds, the *rate* of flux change is different, but what about the *total* flux change, added up over the whole time of the drop? Does this depend upon the speed of coil movement? [Note: There is an "area-under-curve" tool  in the software, and $\Delta\Phi_B = \int \frac{d\Phi_B}{dt} dt$. To use this, select the part of the graph that you which to integrate using the  tool.]
- Do the polarity of the magnet and the sign of the induced emf agree with Lenz's law?

You can take screen shots of what is displayed on the laptop for your lab report to help you make clearer descriptions of the behavior of the induced emf under various conditions.

Part 2

The point to this experiment is to confirm Faraday's law with a known magnetic field. Clearly the signal generator is providing the measurable current that makes this field, but we only have a limited knowledge of field strength in the vicinity of a loop of current. We need to exploit this knowledge to be able to claim that we know the (approximate) field strength. Some questions to consider as you work your way through this:

- Are the frequencies of the oscillating current and induced emf equal? Should they be?
- Is the orientation of the probe (e.g. standing upright vs. laying on its side) important to the experiment?
- We know that the current varies sinusoidally, and we know the frequency of that oscillation. How do we go from this to induced emf?
- What do you think are the biggest sources of error in the experiment, and approximately what is the weakest link percentage error? Do your results confirm Faraday's law within this margin?

You can take screen shots of what is displayed on the laptop and pictures of the oscilloscope output (and knob settings) for your lab report.

Lab Report

Craft a lab report for these activities and analysis, making sure to include every contributing group member's name on the front page. You are ***strongly encouraged*** to refer back to the Read Me as you do this, to make sure that you are not leaving out anything important. You should also feel free to get feedback from your lab TA whenever you find that your group is at an impasse.

Every member of the group must upload a separate digital copy of the report to their lab assignment in Canvas *prior to leaving the lab classroom*. These reports are not to be written outside the lab setting.