PHYS 202L Faraday’s law of electromagnetic induction Name:\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Purpose: Study the Faraday’s law of electromagnetic induction using the PhET Simulation: Faraday’s Electromagnetic Lab.

Introduction: Watch this video <https://www.youtube.com/watch?v=Y18N-hi5P1o>

A. Magnetic Fields

Procedure:

1. Open the following PhET Simulation, Faraday’s Electromagnetic Lab.

<https://phet.colorado.edu/sims/cheerpj/faraday/latest/faraday.html?simulation=faraday>

1. Here you will find a compass and a bar magnet. What do the two have in common?
2. Slowly move the compass around the bar magnet. What observations do you make?
3. Place the compass next to the South Pole of the bar magnet and click “Flip Polarity”. What happens to the magnet and the compass?
4. Click “See Inside Magnet”. Describe what you see.
5. Click “Show Field Meter”. Use the field meter to observe the magnetic field values at different places, including inside the magnet, and locate the position where the magnetic field is the highest. Also, record the highest magnetic field.   
     
   Location where the magnetic field is the highest =\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Value of the highest magnetic field =\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

1. Uncheck “Show Compass”. Move the magnet to the far left as shown below.

|  |  |
| --- | --- |
|  |  |

1. Move the field meter to a location about 1 cm from the north pole, as shown above. Assume that each compass location is about a cm apart. Also, make sure that **By** is very small. Record the **Bx** (=**B**) values as a function of distance as shown below in Excel.

Magnetic field VS. distance Data for a bar magnet:

Bar Magnet Strength = 75%

|  |  |
| --- | --- |
| Distance from N pole (cm) | Magnetic Field,  **Bx** (=**B**), Gauss |
| 1 |  |
| 2 |  |
| 3 |  |
| 4 |  |
| 5 |  |
| 6 |  |
| 7 |  |
| 8 |  |
| 9 |  |
| 10 |  |

1. Plot Magnetic Field VS. Distance, add an appropriate trendline, determine how the field changes with distance, and insert your graph below.

B. Lenz’s law: The current from the induced emf will produce a magnetic field, which will always oppose the original change in the magnetic flux.

Procedure:

1. Click on the second tab, Pickup Coil, of the [simulation](https://phet.colorado.edu/sims/cheerpj/faraday/latest/faraday.html?simulation=faraday).
2. Here you have a bar magnet and a coil (2 turns) of wire attached to a light bulb, which is off. Blue dots in the coil of wire represents the electrons.
3. Describe two ways to light the light bulb.
4. Keep the magnet to the left along the axis of the coil, move the N pole towards the center of the coil, observe what happens, and record the results in the data table below.
5. Keep the N pole at the center of the coil, move the N pole away from the center of the coil, observe what happens, and record the results in the data table below.
6. Click “Flip Polarity”.
7. Keep the magnet to the left along the axis of the coil, move the S pole towards the center of the coil, observe what happens, and record the results in the data table below.
8. Keep the S pole at the center of the coil, move the S pole away from the center of the coil, observe what happens, and record the results in the data table below.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Motion of the magnet | In the Pickup Coil | | | |
| Direction of the applied/external magnetic field along the axis | Direction of electron flow in the front of the coil  (up or down) | Direction of current flow\* in the front of the coil  (up or down) | Direction of the induced magnetic field along the axis (to the left or right) [use the right-hand-rule #2\*\*] |
| N-pole moving towards the coil | Increases to the right |  |  |  |
| N-pole moving away from the coil | Decreases to the right |  |  |  |
| S-pole moving towards the coil | Increases to the left |  |  |  |
| S-pole moving away from the coil | Decreases to the left |  |  |  |

\* Direction of current flow is in the opposite direction of electron flow.

\*\****Right-Hand Rule No. 2.*** Curl the fingers of the right hand into the shape of a half-circle. Point the thumb in the direction of the conventional current *I*, and the tips of the fingers will point in the direction of the magnetic field **B**.

1. Summarize how the above observations validate Lenz’s law.

C. Electromagnet

Procedure:

1. Click on the third tab, Electromagnet, of the [simulation](https://phet.colorado.edu/sims/cheerpj/faraday/latest/faraday.html?simulation=faraday).
2. Here you have a coil of wire (4 turns) connected to a battery set to 10-V. Electrons and hence current is flowing through the coil, which produces a magnetic field. Complete the first row in the data table below.
3. Reverse the direction of current flow by changing the orientation of the battery and complete the second row of the data table.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Battery orientation | In the Coil | | | |
| Direction of electron flow in the front of the coil  (up or down) | Direction of current flow\* in the front of the coil  (up or down) | Direction of the magnetic field along the axis of the coil (to the left or right)  [use the right-hand-rule #2\*\*] | Is it consistent with the compass orientation? |
|  |  |  |  |  |
|  |  |  |  |  |

\* Direction of current flow is in the opposite direction of electron flow.

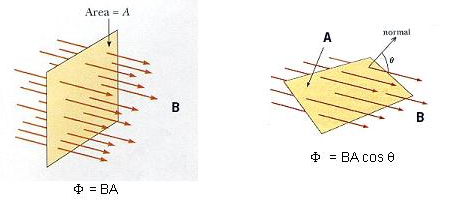
\*\****Right-Hand Rule No. 2.*** Curl the fingers of the right hand into the shape of a half-circle. Point the thumb in the direction of the conventional current *I*, and the tips of the fingers will point in the direction of the magnetic field **B**.

1. Click “Show Field Meter”, and measure the magnetic field at the center of the coils. Repeat the measurements for loops 3,2,1 and record your results in the data table below.

|  |  |
| --- | --- |
| Loops | Magnetic field (G) |
| 4 |  |
| 3 |  |
| 2 |  |
| 1 |  |

D. **Electromagnetic Induction: Faraday’s Law**

When a magnet is passed through a coil there is a changing magnetic flux, Φ through the coil which induces an electromotive force, emf, also known as voltage. According to Faraday's law of induction the induced emf, *ξ* is given by; where *B*┴ is the magnetic field perpendicular to the area *A* and *N* is the number of turns in the coil.



 ****is the magnetic flux for one turn.

Procedure:

1. Click on the fifth tab, Generator, of the [simulation](https://phet.colorado.edu/sims/cheerpj/faraday/latest/faraday.html?simulation=faraday).
2. Here you will find a water faucet (slider-bar to control water flow is on the handle), a compass, a bar magnet fixed to a wheel (turbine), and a coil of wire (2 turns) connected to a light bulb. Blue dots in the coil of wire represent the electrons.
3. Click “Show Field” to display the magnetic field. It can be seen that the compass is aligning along the magnetic field, the magnetic field is passing through the circular coils, and the light bulb is off. Explain why the light bulb is off now, using Faraday’s law.
4. Turn on the faucet, just enough to get 10 RPM on the turbine, and describe what you observe.
5. Increase the Bar Magnet strength to 100% and describe what happens.
6. Increase the Loops to 3 and describe what happens.
7. Click on the voltage meter to replace the light bulb with the voltage meter. This meter has + and – sides, with 5 major divisions on each side. Each major division is divided into 4 smaller divisions for a total of 20 smaller divisions on each side. Assume that each smaller division is equivalent to 1 volt, for a maximum voltage of 20 volt, on each side.
8. For 10 RPM, read the maximum voltage, and record it below. Repeat the measurements for other RPM’s and complete the data table. It will be difficult to read maximum voltage when the RPM is high. Pausing the simulation and using Step will be helpful here.

Bar Magnet strength = 100%, Loops =3 Type of emf/voltage induced =\_\_\_\_\_\_\_\_\_\_

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| RPM | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 |
| Maximum  Voltage |  |  |  |  |  |  |  |  |  |  |

E. Write an overall conclusion: