**PHYS 212L Induction and Permeability Constant**

**Name: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_** **Partner(s):\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**

**Watch the following video:** [**https://www.youtube.com/watch?v=Y18N-hi5P1o&t=6s**](https://www.youtube.com/watch?v=Y18N-hi5P1o&t=6s)

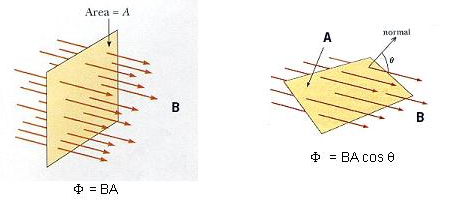
1. **Electromagnetic Induction**

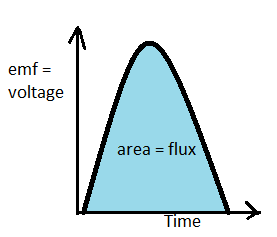
**Purpose:** Investigate the electromotive force (emf) induced in a solenoid by a moving magnet.

**Theory: Faraday’s law**

When a magnet is passed through a coil there is a changing magnetic flux through the coil which induces an electromotive force, **emf (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.   


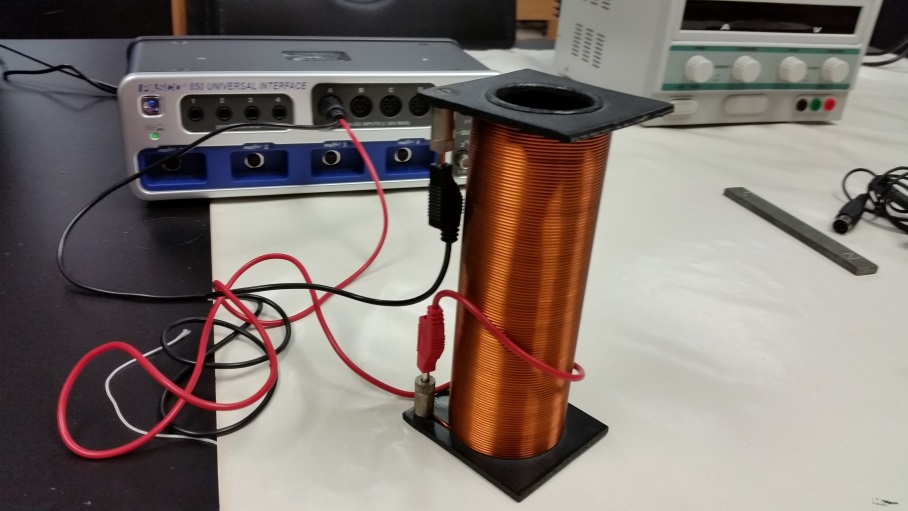


;In this activity, a plot of the emf (or Voltage) *versus* time is made and the area under the curve represents the magnetic flux.

**Apparatus:** PC w/interface (Pasco 850), voltage sensor, solenoid (# of turns =540), magnets (bar and horse-shoe), and soft-box (to catch the magnet).

**Procedure:**

1. Setting up the Interface:   
   a. Make sure that the power for the interface is turned on.  
   b. Connect the voltage sensor to analog input A.  
   c. Plug in the red and black leads from the voltage sensor to the solenoid, place the solenoid vertically on the lab table.

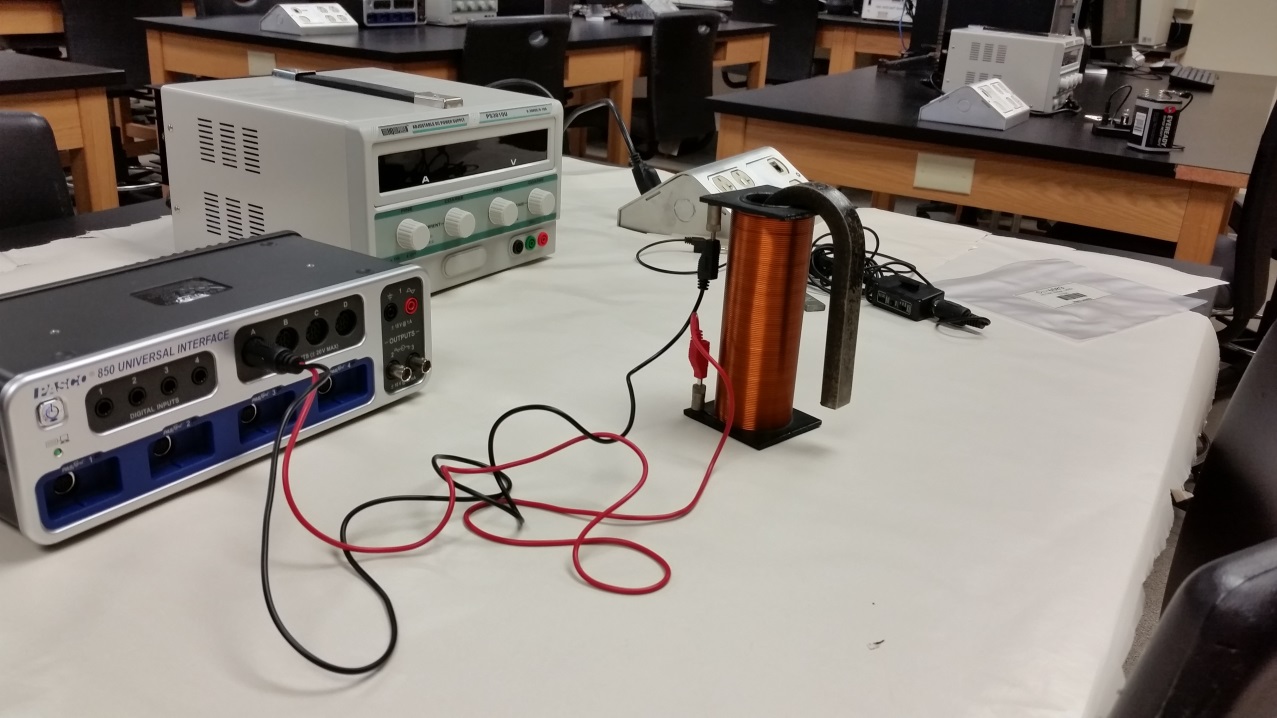


d. Open **PASCO Capstone** software from the desktop.   
e. Click Hardware Setup under Tools on the left, click on the interface input where the sensor is connected, and select **Voltage Sensor**. Click Hardware Setup again to close it.  
f. In the bottom panel, middle, increase the sample rate to 200 Hz.  
g. Click **Recording Conditions**, in the bottom-panel, and do the following:

|  |  |  |
| --- | --- | --- |
| I. Start Condition: | II. Stop Condition: | III.Click, OK. |
| Condition type = Measurement Based  Data Source = Voltage (V)  Condition = Is above  Value = 0.05  Pre-Record = Box checked Pre-Recording time = 0.3 s | Condition type = Time Based  Record time = 0.4s |

h. Click **Graph** under displays on the right, click **Select Measurement** on the Y-axis, and choose Voltage (V).

2. Place one end of the horse-shoe magnet inside the solenoid.



3. Click **Record** and remove the horse-shoe magnet.

4. If nothing is displayed; stop the data collection, place the other side of the horse-shoe magnet and try Procedure (3) again.

5. Maximize the graph display.

6. Measure the peak value of the induced voltage using the **Show Coordinates Tool** and the magnetic flux (area under the V vs. t graph) using the **Display area under active data tool**.

7. Repeat procedures 3-6, for removing the magnet quicker, and complete the data table for the horse-shoe magnet.

8. Place the soft-box on the floor close to the edge of the table and hold the solenoid vertically above it.



9. Click **Record** and drop the bar magnet, N-pole down, through the solenoid.

10. The data collection will stop automatically. You should see two peaks.

11. Magnetic flux is obtained by finding the area under the V vs. t graph. Save a screenshot of the display.

12. After completing the data tables, and answering the questions, close Pasco Capstone.

**DATA:**

a. Horse-shoe magnet

|  |  |  |
| --- | --- | --- |
|  | Slow removal | Quick removal |
| Peak value of the induced emf |  |  |
| Magnetic flux (Area under the V vs. t graph) |  |  |

Q1. Why the magnitude of the peak value of the induced emf is higher for the quick removal?

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Q2. Is the magnitude of the magnetic flux equal for the two peaks? Explain why.

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b. Bar magnet: include units

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Bar Magnet | Dropping the magnet from closer to the solenoid | | Dropping the magnet from further to the solenoid | |
| First Peak | Second Peak | First Peak | Second Peak |
| Peak value of the induced emf |  |  |  |  |
| Magnetic flux (Area under the V vs. t graph) |  |  |  |  |

Q1. Is the magnitude of the magnetic flux equal for the two peaks? Explain why.

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Q2. Why the magnitude of the peak value of the induced emf is higher for the second peak?  
  
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Q3. Describe how the display will change if the S-pole is down when the bar magnet is dropped.

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 Q4. Click Start again and drop the bar magnet, this time S-pole down, through the solenoid. Describe and explain what you see. Does this support your prediction in Q3?  
  
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1. **Purpose: Determine the** [**permeability of free space**](http://scienceworld.wolfram.com/physics/PermeabilityofFreeSpace.html) **(µ0) by measuring the magnetic field of a solenoid as a function of the electric current passing through it.**

**Apparatus:** Solenoid (# of turns =540), magnetic field sensor, PC with Pasco 850-interface, foot-ruler, power supply, and two banana-plug wires.

**Theory:** Visit the following website.

<http://www.pa.msu.edu/courses/2000fall/PHY232/lectures/ampereslaw/solenoid.html>

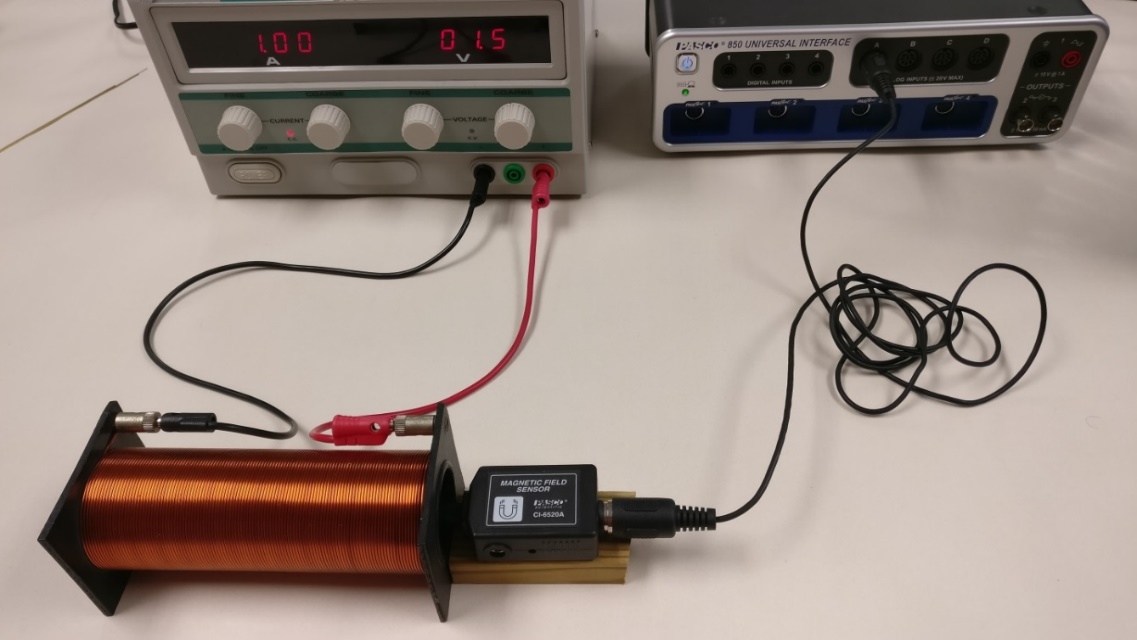
|  |  |  |
| --- | --- | --- |
| http://edugen.wiley.com/edugen/courses/crs1650/art/images/halliday8019c29/image_t/tfg020.gif | http://hyperphysics.phy-astr.gsu.edu/hbase/magnetic/imgmag/amlaw.gif |  |

**Procedure:**

1. Set the magnetic field sensor as follows: Range Select = 1X and AXIAL, as shown below.



1. Connect the solenoid to the power supply, Magnetic Field Sensor to analog input A,   
   insert the magnetic field sensor inside the solenoid, and place it on the small wooden block, as shown below.



3. Setting up the Interface:  
 a. Open Pasco Capstone from Desktop.  
 b. Click **Hardware Setup** under Tools on the left, click on the interface input where the sensor is connected and select **Magnetic Field Sensor**.   
 c. Click **Hardware Setup** again to close it.   
 d. Click **Data Summary** on the left, click **Magnetic Field Strength (1X)(T)**.   
 e. Click on the **gear symbol** on the right, under **Numerical Format**, and change the **fixed decimals** to 5.   
 f. Click **Data Summary** again to close it.  
 g. Click **Digits** under Displays, click **Select Measurement**, and select **Magnetic Field Strength (1X)(T).**

4. Tare the magnetic field sensor when the current is zero, and before putting the sensor inside the solenoid.

5 Set the current to about 0.5A, it doesn’t have to be exactly 0.5 A, click **Record**, and measure the magnetic field. If the reading is negative, reverse the connections to the solenoid.

6. Repeat the measurements by increasing the current by about 0.5A, until you reach about 4A. Do not increase the current more than 4A.

7. Tabulate your Current and magnetic field data in Excel.

DATA: # of turns = N = 540 Length of solenoid = L = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

|  |  |
| --- | --- |
| Current, I (A) | Magnetic Field, B (T) |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |

8. Plot the graph B versus I, obtain the permeability of free space, and attached it to your lab report.

9. Compare the permeability to the accepted value.

Magnetic field of a solenoid is given by: I

Accepted permeability of free space = µ0 = 1.257 x 10-6 T.m/A

Measured permeability of free space = µ0 = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

% Error = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**10. Write a conclusion**