Electromagnetic Induction

TA's signature allowing you to take the quiz or leave ____________

Your Name ______________________________

Partners' Names ______________________________

____

Obtained reasonable experimental results?	yes ☐
Answered questions?	yes ☐
Cleaned your table?	yes ☐

The magnet is very fragile. Exercise caution while dealing with the bar magnet.

Introduction

A current flow creates the magnetic field that is shown by the previous lab. Then, how about the reverse process? Can we create a current with magnetic fields? The answer is yes. However, a steady magnetic field will not create any current. One way to create electricity is to let a magnet move around a coil. This is known as Faraday's law and the expression is:

$$V = -N\frac{d\Phi}{dt}$$

where V, N, and Φ are the voltage induced, the number of turns of a coil, and the magnetic flux, respectively. The negative sign in Faraday's law indicates that the voltage is induced in the opposite direction, which is determined by Lenz's law. This depends on not only the moving directions of a bar magnet, but the orientation of poles of the magnet. The magnetic flux is expressed by the magnetic field times an area where the magnetic fields go through.

$$\Phi = BA\cos\phi$$

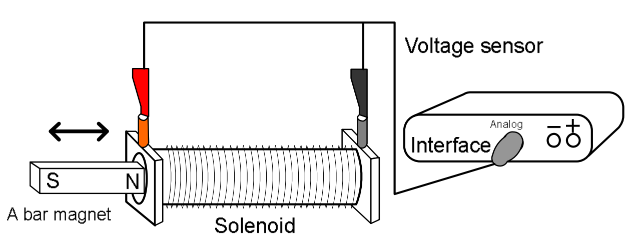
The angle, ϕ, has to be taken from the vertical; thus, when the magnetic field and the area are perpendicular each other, the angle, ϕ, becomes 0^o, which gives $\cos 0^o = 1$. The SI unit of the magnetic flux is weber (Wb).

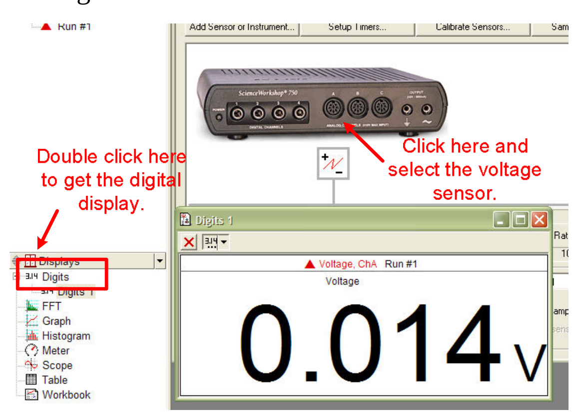
Objectives:
- To learn how a magnet creates voltage (magnetic flux and Faraday's law)
- To see which direction the voltage induced according to the motion and orientation of the magnet (Lenz's law)

1. Magnetic induction and Faraday's and Lenz's laws

- **Conceptual Activity (Qualitative Experiments)**

① Set up the equipment as shown in the figure.
② Start up DataStudio, select the voltage sensor, and display the digital meter as illustrated.

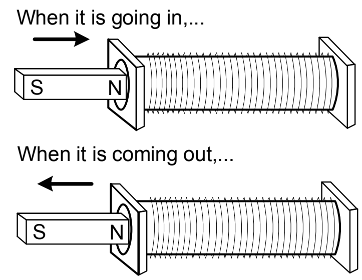




You will investigate how the induced emf (voltage) depends on each change. Describe briefly after the experiment, answer the following questions:

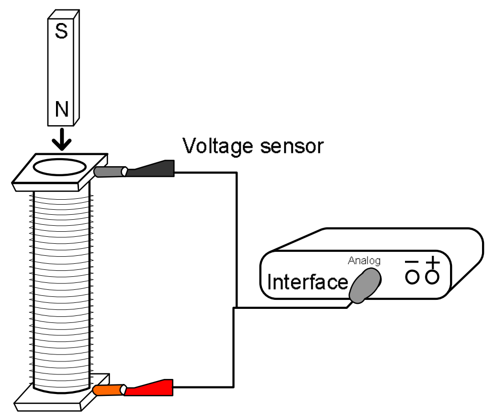
❶ How does the emf change by the speed of the magnet in the solenoid? (*Read the maximum value to evaluate this qualitatively.*)

❷ How does the maximum emf change with different magnets (different strength of magnetic fields) with about an equal speed? Or how quickly do you have to move the weak magnet to reach the maximum magnetic field that the strong magnet does?



❸ Keep the orientation of the magnet (N-pole directed to the solenoid). How does the polarity of voltages (positive or negative) depend on the directions of movement?

❹ What is a main difference when you change the orientation of the magnet (S-pole directed to the solenoid) in experiment ❸?



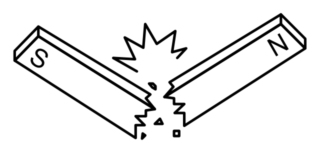
2. Electromagnetic induction due to a falling magnet

The magnitude of the induced voltage (emf) can be described as

$$|V| = N\frac{d\Phi}{dt}$$

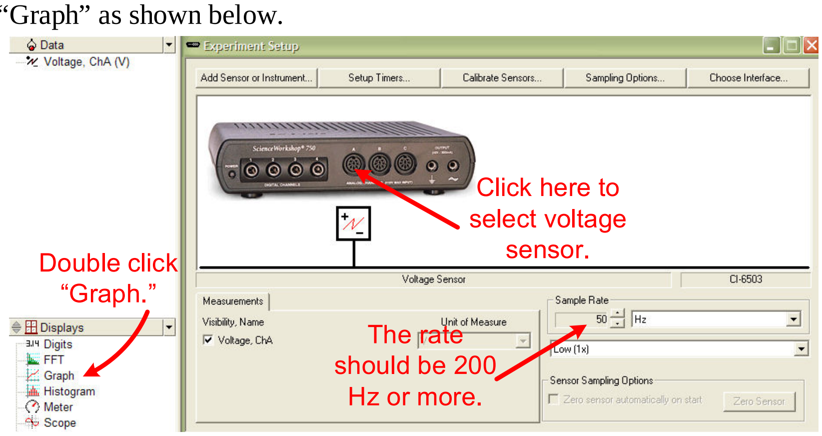
The N is the number of turns, the Φ is the magnetic flux (The unit is Wb.) obtained from the magnetic field of the magnet, B, and the cross-sectional area of the solenoid, A. The term, $\frac{d\Phi}{dt}$, illustrates the change of the flux with respect to time.

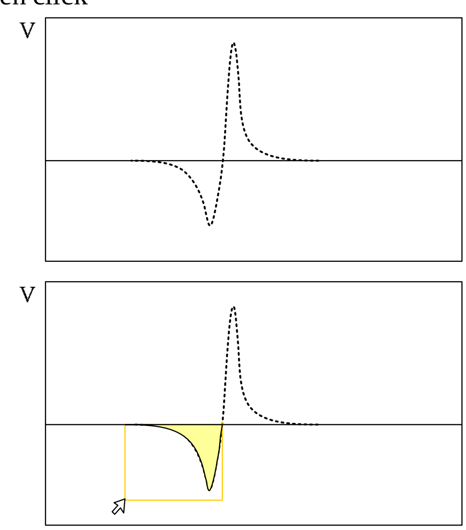
Do not drop the magnet on a hard surface.



Procedure:

① Start up DataStudio. Click "Create Experiment", and follow the picture illustration. The sampling rate should be at least 200 Hz. If needed, it can be increased. Then click "Graph" as shown below.





② Click start and drop the magnet from 1 cm above the coil. (Try to catch the magnet or drop on a soft surface.) You will obtain the following graph in DataStudio.

③ Record the voltage induced. Change the orientation of the bar magnet fallen into the solenoid.

④ Click and select the area as follows:

Print it out.

⑤ The area is proportional to the magnetic flux. Record each area as the flux.

Repeat the same trial two times.	**Magnetic flux from the experiment** **(Don't forget the unit.)**
Trial 1: ingoing peak ⇨	
Trial 2: ingoing peak ⇨	
Average of the above data ⇨	

Calculation

The voltage induced is given as

$$|V| = N\frac{d\Phi}{dt}$$

Thus, the magnetic flux per turn can be solved as

$$\Phi = \frac{t|V|}{N}$$

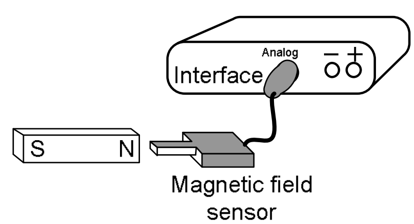
The time × voltage is obtained from the area in the previous part. The total number of turns of the solenoid is 1340.

$\Phi = \frac{t\lvert V\rvert}{N} =$ ______________________________ (   ) ⇐ units   (1)

On the other hand, the flux is also given as

$$\Phi = BA$$

where B is the magnetic field from the magnet, and A is the cross-sectional area of the solenoid. (Note that the B and A are perpendicular each other.) Measure the area and magnetic field and calculate the magnetic flux.

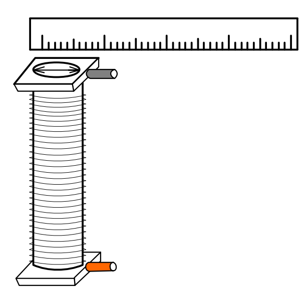


B (with a magnetic field sensor) =

______________________________ (teslas)

(If you measure with gauss, multiply by 10^{-4} to obtain tesla.)

[Make the tip of sensor contact with the edge of the magnet.]



Measure the diameter of solenoid = ____________________ (   ) ⇐ units

Divide the diameter by 2 to obtain the radius = ______________ (   ) ⇐ units

A (area of the circle) πr^2 = ________________________ (   ) ⇐ units

Φ (flux) = BA = ______________________________ (   ) ⇐ units   (2)

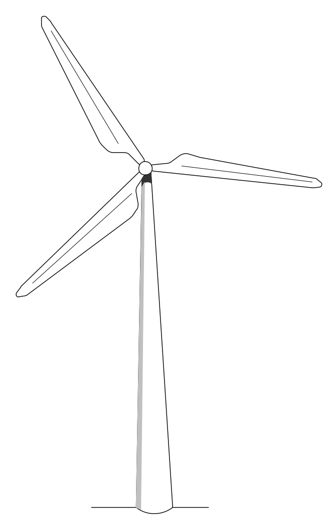
Question:
Do you obtain similar values in (1) and (2)? You may not obtain a better percent difference. Think about following:

- The bar magnet is falling and each instant the cross-sectional area takes different angle of magnetic fields. How does it affect the result?

- A magnet may have a different property. Why don't you measure the magnetic field with different angles with the magnetic field sensor? (Try this with a different bar magnets, too.)

- This is solenoid, which is a long coil. Does the shape affect the result? What if it is a normal coil?

Questions you want to explore:



This lab illustrates how a magnet in motion toward a coil creates electricity. This principle is applied to wind energy, thermal and hydroelectric power generations, etc.

- What are the mechanisms of these generators? Where is the magnet and coil in the system?

- Look for any generators in your daily life using this principle.