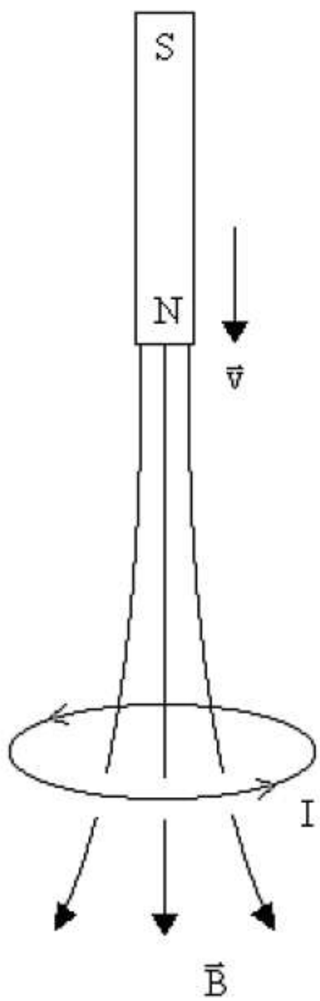
Experiment #11 Faraday's Law Pre-lab

**** Disclaimer: This pre-lab hint is *not* to be copied, in whole or in part, unless a proper reference is made as to the source. (It is strongly recommended that you use this document *only* to generate ideas, or as a reference to explain complex physics necessary for completion of your work.) Copying of the contents of this web site and turning in the material as "original material" is *plagiarism* and will result in serious consequences as determined by your instructor. These consequences may include a failing grade for the particular pre-lab or a failing grade for the entire semester, at the discretion of your instructor. ****

**** Note that a lot of the information given below is very complicated. If you do not understand what is going on here, don't feel bad – because most physicists have trouble fully understanding this part of physics as well. ☺ ****

- **Here is the setup; a magnet is dropped through a loop of wire.**



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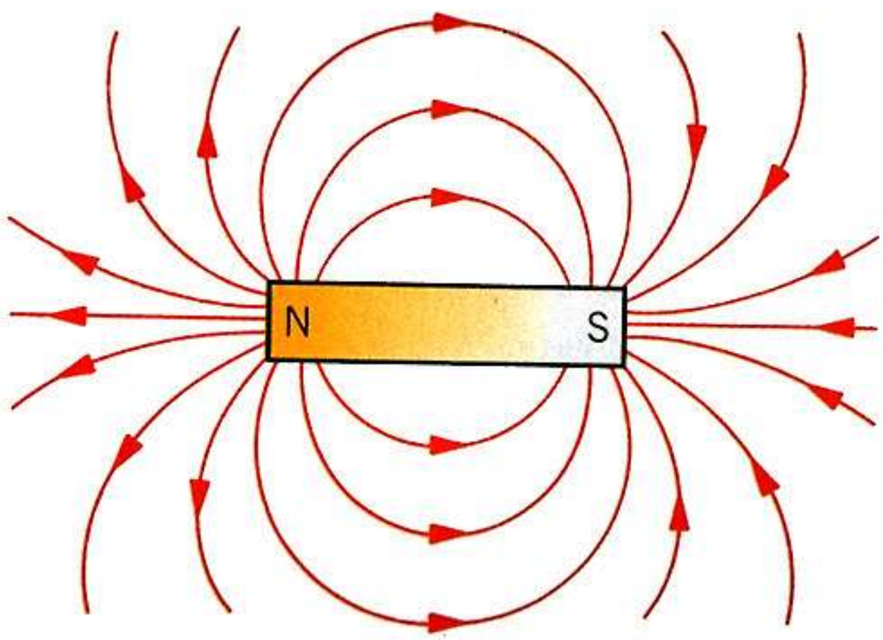
- **Describe how the value of the magnetic field changes (at the loop) as the magnet approaches the loop.**

The following is a plot of the Magnetic Field of a bar magnet. Notice that as you approach the North Side of the Magnet, there are more and more lines that are passing though a constant area. This is precisely the flux though an area.



Hence, the flux of the magnetic field though a constant area increases as the magnet approaches the loop.

- **How does the field change after the magnet passes through and receding form the loop?**

Again look at the image above. Once the magnet passes the North side, there are fewer and fewer lines passing through the constant loop. This means that the flux will drop off till it reaches a point of zero exactly at the center of the magnet. At that point there being to be a few more lines of the magnetic field that are pointing in the opposite direction. This will change the sign on the flux an start decreasing till it hits the south pole where there will be a large number of magnetic field lines passing though the constant area. As the constant area moves further away from the south pole, again there will be fewer and fewer lines passing through the area, hence the magnetic field's flux will drop off toward zero again. (Now go look at the picture 2 questions down and see if this is precisely what is happening in that graph.)

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- **How does the EMF in the loop change if we double the number of loops, holding everything else constant?**

From the lab procedures, the EMF is defined as:

$$\varepsilon = -N \frac{d\Phi_B}{dt}$$

Where N is the number of loops of the wire, and $\frac{d\Phi_B}{dt}$ is the time rate of change of the magnetic flux though a given constant area.

By examining the equation above, we see that if we double the number of loops in the coil, we will effectively double the EMF generated in the loop by the magnet moving though the loop.

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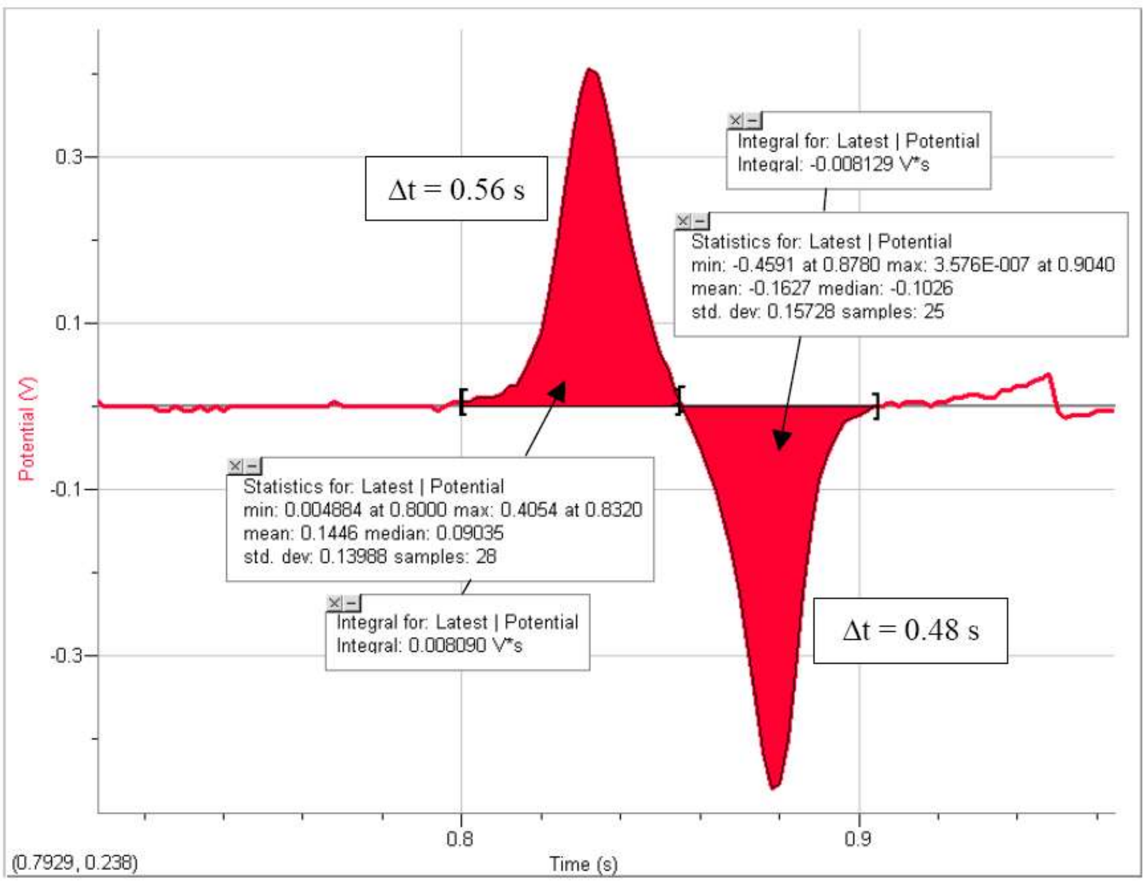
- **The following graph is the result of a magnet being dropped through a coil of wire from the height of 0.43 m.**



**** WARNING: The times in the graph above are off by a factor of 10. They should be 0.056 s and 0.048 s respectively!! ****

- **What is the average velocity of the magnet when it reaches the coil?**

The average velocity if found using the Energy Equation (recall back to Physics 115 for how we did this). The energy equation says:

$$U_{Initial} + K_{Initial} = U_{Final} + K_{Final}$$

Where U = Potential Energy and K = Kinetic Energy.

Let us establish our initial and final conditions:

$$U_{Initial} = mgh$$
$$K_{Initial} = 0$$
$$U_{Final} = 0$$
$$K_{Final} = \frac{1}{2}mv^2$$

This means that:

$$mgh = \frac{1}{2}mv^2$$

Solving for velocity:

$$v = \sqrt{2gh}$$

Plugging in the given values:

$$v = \sqrt{2\left(9.81\frac{m}{s^2}\right)(0.43m)}$$

$$\boxed{v = 2.905\frac{m}{s}}$$

- **Is the flux of the incoming magnet equal to the amount of flux of the outgoing magnet? Explain**

On a graph of voltage versus time, the total flux will be the area under the curve from time-1 to time-2. Notice that there is both a magnitude and direction (since the magnetic field is a vector). A positive flux means that the South end of the magnet was passing through the loops and negative flux means that the North end of the magnet was passing through the loops.

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Hence, the incoming magnet's south end flux is between times 0.80 s and 0.856 s on the graph above. Using logger pro, the area under the first curve is 0.008090 Vs.

The magnet's north end flux is between times 0.856 s and 0.904 s. Using logger pro, the area under the first curve is -0.008129 Vs. (Again, notice that it is negative since the magnet's north end is passing through the loops of wire.)

$$0.008090\ Vs \overset{?}{=} 0.008129 Vs$$

These are approximately equal. They only differ by 0.000039Vs (which is close enough to zero). ☺

Some reasons why this is not exactly zero:

1. The strength of the Magnetic field is changing over time.
2. The velocity vector is not in the same direction as the normal to the cross-sectional area (this isn't obvious – but we will try to accomplish this by assuring that the normal is pointing in the same direction as the acceleration vector – thus in the same direction as the velocity vector if we drop an object.) – For this part of the experiment, we will purposely orient the ring of wire so that its surface (will be parallel to the ground) and its normal will point in the same direction as the acceleration due to gravity vector (toward the ground). We will also drop a magnet through the loop, which will have an initial velocity of zero, and will accelerate due to gravity in the same direction as the acceleration due to gravity vector. I've gone though all this explanation to reach the fact that due to the setup of the experiment, we are in attempt trying to make the angle of attack angle (tilt) VERY NEARLY zero, but this is unrealistic, and not easily accomplished.
3. There is likely air resistance inside the tube which affects the velocity of the falling magnet. Furthermore, the farther the magnet falls, there is a gradient of velocity increase the further the magnet travels (since it hasn't reached a critical velocity, yet).

- **Use the Flux rule to explain how change in the time (velocity) affects the peak height (EMF) for each peak?**

**** NOTE: This question is beyond the scope of an Algebra based Physics Lab class. This question requires knowledge of Calculus and Calculus based physics relationships of position, velocity and time. For that reason, this question will not be counted against you for your answer. For good measure, the answer is given below.****

Starting with the Flux rule, $\varepsilon = -N\dfrac{d\Phi_B}{dt}$, notice that we can multiply this by 1 and not change the equation.

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$$\varepsilon(1) = -N\frac{d\Phi_B}{dt}(1) = -N\frac{d\Phi_B}{dt}$$

Now, here's the trick: also notice the following:

$$\frac{dx}{dx} = 1$$

Hence,

$$\varepsilon\left(\frac{dx}{dx}\right) = -N\frac{d\Phi_B}{dt}\left(\frac{dx}{dx}\right)$$

$$\varepsilon(1) = \varepsilon = -N\frac{d\Phi_B}{dt}\left(\frac{dx}{dx}\right)$$

$$\varepsilon = -N\frac{d\Phi_B}{dt}\left(\frac{dx}{dx}\right)$$

Using the commutative nature of derivatives:

$$\frac{du}{dv}\frac{ds}{dt} = \frac{du}{dt}\frac{ds}{dv}$$

We get the following:

$$\varepsilon = -N\frac{d\Phi_B}{dx}\left(\frac{dx}{dt}\right)$$

From PES 115 (and probably lecture from Physics 1), we know that the displacement of the position with respect to time is a velocity:

$$\dot{x} = \frac{dx}{dt} = v$$

Thus:

$$\varepsilon = -N\frac{d\Phi_B}{dx}(v)$$

Now, notice that if the velocity increases, the peak height of the EMF also increases if the number of loops is held constant and the change in flux as a function of position (which is also negative for the north end of a magnet) is held constant.

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- **What is the Total area of the EMF for the magnet drop, the sum of both integrals? Does this make sense? Explain.**

$$0.008090\ Vs - 0.008129\ Vs = -0.000039\ Vs$$

Yes, this makes sense. The sum should be very nearly zero (as discussed 2 questions above). Notice that we've attempted to explain already some of the "issues" related to why this is not exactly zero.

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