Magnetic Induction

Name:	Teammates:

Introduction

We know that a current creates a magnetic field. This means that a moving charge acts on magnets (for example, current in a wire making a compass deflect). By applying Newton's Third Law we can deduce that a magnet can apply a force on a moving charge. Therefore, if you position a magnet near a current-carrying wire that is free to move, the wire would move. This is, in fact, the basis for an electrical motor, where current-carrying wire coils are deflected around an axle when in presence of a magnetic field.

In the previous paragraph, the movement of the charges is due to a potential difference. The question arises, what if the charges were being moved mechanically? Or what if the charges themselves were static, but the magnet was moved? As you will find out in this lab, the change in the magnetic field can cause the charges to move along the wire, thereby creating a current. This is the basis of an electrical generator.

Induction

In 1831, Michael Faraday was able to show that the induced electromotive potential is related to the rate at which the magnetic flux changed within a closed loop, is given by

$$\text{emf} = -N\frac{\Delta\Phi}{\Delta t}$$

where Φ is the magnetic flux through one coil, and N is the number of loops. The flux is given by (refer to Figure 1)

$$\Phi = BA\cos\theta$$

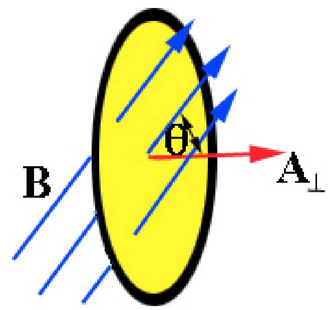


Fig 1: Magnetic flux through A

Faraday's equation shows that the voltage induced in a the loop depends upon how quickly the magnetic flux through the loop changes.

There are many ways to get the magnetic flux through a closed loop to change. In this experiment, we will do this by having a bar magnet, released from rest, fall freely along the central axis of a solenoid. The rate of change of the magnetic flux through the solenoid will be larger if the magnet is moving faster. Thus, we would expect the induced emf to be directly proportional to the speed of the magnet.

If the magnet were to be dropped through a long solenoid, another effect will come into play. The current induced in the coils will in turn produce a magnetic field. This magnetic field tends to oppose the change in magnetic flux (this is again a manifestation of the law of conservation of energy.) This phenomenon is referred to as Lenz's law. This means that the falling bar magnet will feel forces other than that due to gravity. Fortunately, the effect of this magnetic force for the magnet and solenoid used in this experiment is small. Thus, the speed of the center of the bar magnet released from rest as it passes through the center of the solenoid is given by

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

where h is the original height of the magnet above the solenoid and g is the gravitational field strength at that position.

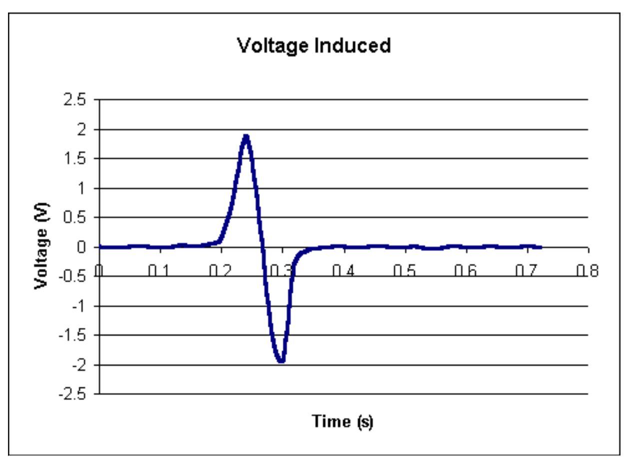


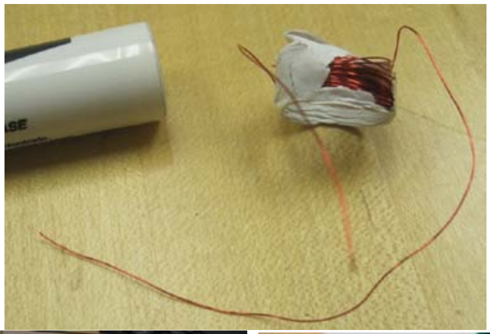
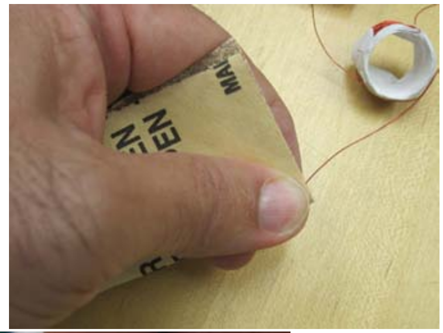
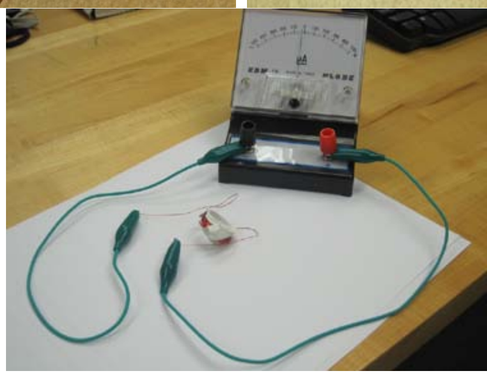
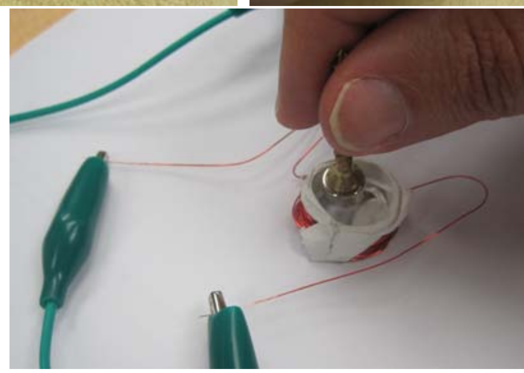
Fig. 2: Voltage from drop magnet through coil

The plot in Figure 2 shows the induced voltage in a solenoid of N=1000 turns by dropping a bar magnet from a height of 20 cm. The emf as a function of time shows a maximum and a minimum. In order to make comparisons of the emf at different speeds of the bar magnet, we will use the average of the magnitudes of the maximum and minimum emf. To test the relationship between emf and rate of change of magnetic flux, a graph of the average of the magnitudes of the maximum and minimum induced emf's versus speed at the midpoint will be constructed.

Procedure

Part 1: Making Electricity

Make a coil of copper wire by wrapping a 2.0 m long copper wire around a marker, holding it together with masking tape and then pulling it off the marker. Scrape the insulation off about 0.5 cm of the wire at each end.

Use alligator clip wires to connect both ends of the coil to a Galvanometer. Approach a strong magnet to the coil and observe what happens. If the readings in the galvanometer are too small for you to decipher, replace the coil by the solenoid. Use the following steps for guidance.

1. Which direction does the galvanometer needle move while you are approaching the magnet?

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2. Which direction does the galvanometer needle move while you are moving the magnet away?

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Explain what you have observed in the previous two steps.

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3. Which direction does the galvanometer needle move if you reverse the magnet then approach it?
Predict what will happen:

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What did you observe?

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4. Would the galvanometer needle move if you simply place the magnet next to the coil?
Predict what will happen:

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What did you observe?

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5. Would the galvanometer needle move if you move the coil instead of the magnet?
Predict what will happen:

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What did you observe?

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7. Would the galvanometer needle move if you simply move the magnet laterally next to the coil?
Predict what will happen:

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What did you observe?

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8. Would the galvanometer needle move if you simply spin the magnet next to the coil?
Predict what will happen:

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What did you observe?

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9. What is the effect of moving the magnet at a faster speed towards the magnet?
Predict what will happen:

....

What did you observe?

....

10. How would the number of coils affect the amount of electricity induced? Compare the use of the coil you made to the use of the solenoid. The solenoid allows you to use three configurations for further testing.:

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11. How would you use the right hand rule to predict the direction of current flow in the coil? It is easier to refer to the coil you made for that.

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12. Can you think of another method (s) that will result in a galvanometer deflection?

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From the experiments that you have just completed, what is your conclusion on what is necessary for inducing current into the coil?

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Part 2: Eddy Currents

Secure the long copper tube, the long plastic tube, the foam cushion and the small disk magnet that you have used in part one. Check whether the tube attract the magnet.

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1. Hold the plastic tube vertically above the cushion and drop the magnet inside the tube. Pay attention to how fast it falls.
2. Hold the copper tube vertically above the cushion and drop the magnet inside the tube. How does the fall time compare to the fall in part 1?

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3. What do you think have affected the fall time of the magnet when it was dropped within the copper tube?

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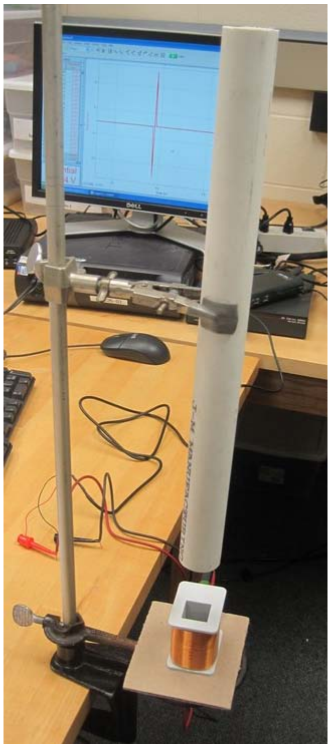
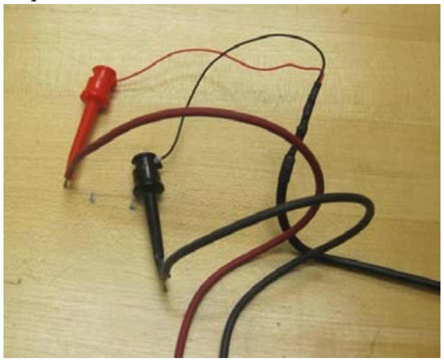
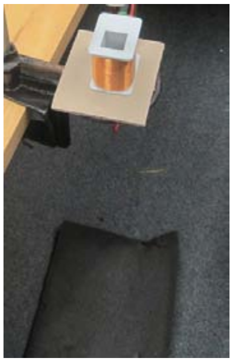
Part 3: Induction Experiment



For this activity, you will need a bar magnet, a 2400 coil solenoid, a meter stick, a table stand with 1 ring clamps and one 90^{o} clamp, a foam cushion, and a Vernier voltage probe.

1. Set up the equipment as in the Figure. Position the PVC pipe so that it is above the middle of the solenoid.
2. The purpose of the PVC pipe is to help you drop the magnet through the solenoid. You can use the meter stick for the same purpose.
3. Position the bar magnet such that its bottom is at a distance of 0.1 meter above the center of the solenoid. You may use the three disk magnets to position the bar magnet at the position of your choosing within the PVC pipe.
4. Start the LoggerPro software and open the “induction” settings file. If you cannot find it, download it from the physics site.
5. With the magnet in position over the solenoid, press the collect data button.
6. Drop the magnet through the solenoid, making sure the magnet lands on the cushion.
7. Use the zoom feature of the software (drag the mouse over the area of interest, focus on the darker of the two shades seen, and use the right click to zoom in) to record the maximum and minimum voltages using.
8. Repeat this twice more at this height, averaging the absolute value of the maximum and minimum voltages. Record this data on the activity sheet.
9. Raise the bar 0.1 m and repeat the previous steps. Continue until you reach a height of 0.5 m.
10. Assume that the friction with the wall of the PVC pipe to be small, calculate the speed of the bar at the middle of the solenoid for each height.
11. Plot the average voltage magnitude versus the speed.
12. Answer the questions.





Height	Min 1	Max 1	Min 2	Max 2	Min 3	Max 3	Average	Speed
.1 m								
.2 m								
.3 m								
.4 m								
.5 m								

1. Why is the maximum positive emf different from the maximum negative emf?

2. What is the relationship between the speed of the magnet and the maximum emf?

3. What is the effect of changing the direction of the magnet?

4. What other factors can you possibly change to still induce an emf?

5. What factors can you possibly change to increase the flux through the coils?