Experiment 12: Magnetic Induction

Pre-lab questions

This lab contains many activities which are tough to visualize without seeing the apparatus. You will thus not gain much by reading it. These pre-lab questions will therefore review fundamental concepts of electricity and magnetism instead.

1. (0.8 point) What is the direction of the Lorentz force $\vec{F} = q\vec{v} \times \vec{B}$?

   a. Perpendicular to $\vec{v}$ and parallel to $\vec{B}$.

   b. Perpendicular to $\vec{B}$ and parallel to $\vec{v}$.

   c. Perpendicular to both $\vec{v}$ and $\vec{B}$.

2. (0.8 point) How does the Lorentz force $\vec{F} = q\vec{v} \times \vec{B}$ change if $\vec{v}$ reverses?

   a. It does not change. b. It drops to zero. c. It reverses.

3. (0.8 point) How does the Lorentz force $\vec{F} = q\vec{v} \times \vec{B}$ change if $\vec{B}$ reverses?

   a. It does not change. b. It drops to zero. c. It reverses.

4. (0.8 point) If particles with electric charge q move with velocity $\vec{v}$, in what direction is the resulting current I?

   a. I is in the same direction as $\vec{v}$. b. I is in the direction opposite $\vec{v}$.

   c. I is in the same direction as $q\vec{v}$. d. I is in the direction opposite $q\vec{v}$.

5. (0.8 point) What must exist for an electric potential to be induced around a closed loop?

   a. An electric field through the loop.

   b. A magnetic field through the loop.

   c. An electric field change through the loop.

   d. A magnetic field change through the loop.

These questions are provided for your convenience. Submit your answers to these questions on Sakai before the first lab period begins. Do not submit them in your lab section.

EXPERIMENT 12. MAGNETIC INDUCTION

12.1 Problem

- How are electricity and magnetism related? How do they affect each other?
- What are some applications of electromagnetic effects?

12.2 Equipment

electromagnetic demonstrations as set up by the lab instructor, liquid nitrogen

12.3 Background

Each demonstration in this lab illustrates one or more electromagnetic principles. These include:

> **Ampere's Law**: an electric current (or any changing electric flux) induces a magnetic field.
>
> **Faraday's Law**: a changing magnetic flux induces an electric field (and hence a current).
>
> **Lenz's Law**: the direction of an induced electric field opposes the magnetic flux change that created it.
>
> The **Right Hand Rule**: If the index finger of your right hand points in the direction of the current and your palm faces the direction of the magnetic field, then your outstretched thumb points in the direction of the force.

Note that Lenz's law is basically a conservation law. A system tries to conserve its original state by opposing any change in that state.

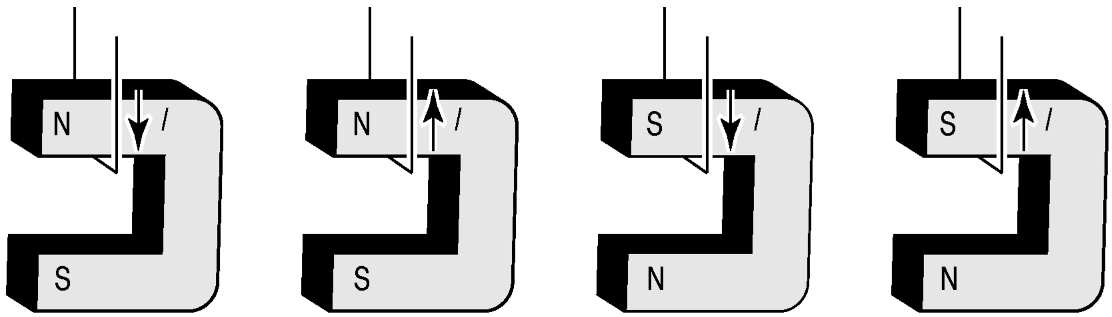
There are eleven stations in this lab. You may do them in any order. Several questions accompany each station and you should answer these questions after experimenting with the apparatus. The questions will provide a guide for your experimentation; try to predict what will happen in each case before trying it. Make sure you do all of the activities before leaving the lab. Each question is worth 0.4 point.

12.4 Activities

1. Magnetic Force on a Current-Carrying Wire

In this demonstration, think about which way the current is going through the wire.

1.1 Set up all four combinations of magnet and current polarity, as shown below. For each combination, what is the direction of the force on the swinging wire? Draw arrows to indicate.



1.2 What is the direction of $\vec{B}$ and $q\vec{v} \times \vec{B}$ in each of the four combinations? Draw arrows to indicate directions below each combination. (It nay help to draw arrows for $\vec{B}$ and $q\vec{v}$ between the poles of the magnet as well.)

$\vec{B}$:

$q\vec{v} \times \vec{B}$:

1.3. What can you do to reverse the direction that the wire swings?

2. Bar Magnet and Coil

2.1. How can you make the galvanometer needle deflect?

2.2. How can you influence the magnitude of the galvanometer deflection? How can you influence its direction?

2.3. What happens when you hold the magnet still inside the coil?

2.4. What happens when the galvanometer wires are reversed?

3. DC Transformer

DC means direct current (as opposed to alternating current). This apparatus consists of two wire coils. One is connected through a switch to a DC power source and the other is connected to a galvanometer, which measures electric current.

3.1. What happens to the galvanometer when you close the switch and leave it closed?

3.2. What happens to the galvanometer when you open the switch and leave it open?

3.3. Why is there no deflection when the switch is held down?

3.4. What happens when the two coils are moved farther apart or closer together? Why?

3.5. What happens when one of the coils is turned around?

4. Suction Coil

4.1. What happens when you close the switch?

4.2. Why does the steel cylinder react, but not the aluminum bar?

5. Transformer

Plug the cord into the 115V AC socket. (AC stands for alternating current.) Think about the magnetic field that is being produced.

5.1. What happens when you plug in the cord? Why?

5.2. What happens when you move the coil marked “H” up along the laminated iron core away from the lower coil marked “2B”?

5.3. Is there a conducting electrical connection between the "H" coil and the "2B" coil?

5.4. Why does the bulb light?

5.5. What would happen if this demonstration were plugged into a 115V DC source? Explain your reasoning. (Compare this demonstration with #3, the DC transformer.)

6. Generator

Inside the magnet there are coils of wire that spin when you turn the crank. Think about what happens to the magnetic flux through the coils as they spin.

6.1. What happens when you close the knife switch and turn the crank? Why?

6.2. Is the crank easier or harder to turn when the switch is open? Explain why, using the principle of conservation of energy.

6.3. Explain how the generator works in terms of mechanical energy, magnetic flux, induced potential, electric current, and electrical energy.

7. Electric Motor

You might have to push the motor a little to make it start. If it still does not start, check your connections, and make sure that the small leads are in contact with the coils.

7.1. What happens to the motor rotation when you reverse the connection on the battery? Why?

7.2. What happens when the poles of the magnets are switched?

7.3. Compare the electric motor with the generator of Demo #6.

8. Ring Fling

STAND BACK when using this demonstration. Remember that metal conducts electricity; think about what happens to the ring with a slit in it and why. Remember that you are using an AC source.

8.1. Place the solid ring around the post. What does it do when you push the button?

8.2. Place the slit ring around the post. What does it do when you push the button?

8.3. What happens when you put the rings on the post together, with the solid ring on top of the slit ring? What happens when you put the slit ring on top of the solid ring?

8.4. Explain the interaction between the iron core and the solid metal ring. Include in your explanation the current in the coil, the magnetic field in the iron core, the current induced in the ring, and Lenz's law.

8.5. Why does this apparatus use alternating current instead of direct current? (*Hint:* what would happen if it used direct current?)

If you soak the solid ring in liquid nitrogen, it becomes a better conductor of electricity. If you have access to liquid nitrogen, try it! (CAUTION: You will need to handle the ring with tongs or gloves!) Think about how this affects the forces in this demonstration. (You do not need to answer anything.)

9. Cathode Ray Tube

Remember that the right-hand rule uses the direction of the electric current, which is *opposite* the direction of the flow of negative charge. In this apparatus, cathode rays, which consist of (negatively-charged) electrons, fly from the back of the tube to the screen.

9.1. What happens to the glowing dot when you hold the magnet near it? Why?

9.2. How does the position of the magnet influence the effect? What happens if you reverse the poles of the magnet?

10. Magnet and Copper Pipe

Think about what is happening to the tube as the magnet falls through it.

10.1. Drop the magnet down the inside of the copper pipe. Does the magnet fall through the pipe more quickly or more slowly than it would fall outside the pipe?

10.2. Look down the pipe as the magnet falls. Is there friction between the magnet and the pipe?

10.3. Drop the magnet down the inside of the PVC plastic pipe. Explain why the magnet falls differently inside the two pipes. (Neither pipe is magnetic!)

11. Magnetic Braking

This apparatus consists of a “C” magnet or two magnets with attracting poles separated by a narrow gap, an adjustable hanger arm, and three non-magnetic aluminum paddles. One of the paddles is configured as a comb (separated tines), one as a spatula (with parallel slots that do not continue to the end), and one is solid.

Verify that the paddles swing freely when no magnet is present. Then position the pivot and magnet so that a hanging paddle rests in the gap between the magnet's poles.

11.1. Hang the comb paddle from the arm, draw it back, and release it to swing through the gap between the magnet poles. Describe its motion.

11.2. Hang the spatula paddle from the arm, draw it back, and release it to swing through the gap between the magnet poles. Describe its motion.

11.3. Hang the solid paddle from the arm, draw it back, and release it to swing through the gap between the magnet poles. Describe its motion.

11.4. Aluminum is not magnetic. Why does the magnet affect the swinging of the paddles?

11.5. Why do the different paddles interact differently with the magnetic field?