

## *Electromagnetic Laboratory Stations*

The following laboratory exercises are designed to help you study magnetic fields produced by magnets and current carrying wires, and study other well-known electromagnetic phenomena.

The order of the experiments will lead you through magnetic field production, the effects of magnetic fields on moving charges and current-carrying wires, the dual nature of moving charges and its effect in electric motors, electric generators, and cathode-ray tubes, and descriptive experiments in Lenz' law, eddy currents, and magnetic levitation using paramagnetism.

During these experiments, you will be making observations and explaining these observations. No numerical data should be taken. You will investigate the electromagnetic phenomena for yourself, so don't watch someone, do it yourself! It is not necessary that you perform the experiments in the order they are written up.

The write up in your lab notebook should consist of a brief description of what you observed, relevant sketches, relevant force diagrams and (for PH 4B students ONLY) descriptions of how the applicable laws (e.g. Faraday's Law and Lenz's Law) explain the observed phenomena.

### **1. Magnetic Lines of Force**

#### 1. Introduction

By using iron filings suspended in oil, we can see the lines of force produced by permanent magnets. Use the 3D or 2D box with permanent magnets to observe these lines.

#### 2. Equipment

3D Magnetic Field observation container  
2D Magnetic Field observation container  
2 cylindrical magnets  
2 flat magnets  
1 horseshoe magnet  
Aluminum weights for spacers

#### 3. Procedure

##### *3D observation container*

- Shake the container until the filings are evenly distributed throughout the box. Insert two magnets in line with one another and sketch the field.
- Reshake the container and insert the two magnets so that they oppose. Do not press them together; just allow them to repel each other. Sketch this field. Option: Shake container, place two magnets on the inside and place another magnet on the outside and draw resulting field.

##### *2D observation container*

- Shake container until the filings are evenly distributed throughout the liquid. Place two or three different magnets under the container, taking care that they don't attract. Sketch the resulting field display.
- If the field is not very clear, use spacers to raise the container above the magnets so that there is some room between the magnets and the container.

## 2. The Electromagnet

### 1. Introduction

Create an electromagnet by passing current through a wire wrapped around a soft iron core.

### 2. Equipment

Soft iron bar or nail

Length of insulated wire

1 or 2 batteries

Paper clips or other light steel objects

Compass

### 3. Procedure, Questions and Analysis

- Wrap the insulated wire around the iron bar as closely and tightly as possible. Leave leads of 20cm long from the coil. Attach leads to the battery terminals
- Check to see if your electromagnet will pick up paper clips and other stuff. Use the compass to determine which end is North.
- What happens to the pole of the magnet if you reverse the battery leads?
- What happens if you use two batteries in series?
- Can you derive a rule for finding the orientation of your battery based on current direction through your battery?

### 4B students:

- Describe what is happening in the iron bar as current is passed through the wire.
- Determine direction of B field using Right Hand rule and knowledge of current direction.

## 3. Magnetic Field of a Solenoid

### 1. Introduction

As current passes through a solenoid, the magnetic field inside the solenoid is nearly uniform.

### 2. Equipment

Solenoid in small black box

Iron filings

Power supply

### 3. Procedure

Turn on the power supply and observe the magnetic field set up by the iron filings in the 3D box.

Sketch the magnetic field set up through the center of the solenoid in the box. NOTE: You may have to collect the iron filings into your hand and then sprinkle them over the solenoid to see them aligned with the solenoid's magnetic field.

## **4. Magnetic Field due to a current through a long wire**

### 1. Introduction

As current is passed through a wire, a magnetic field is generated at right angles to the current. Use this phenomenon to explore the effects on compasses.

### 2. Equipment

Long wire  
Steel pole and table clamp  
Ring stand  
Compasses & cardboard sheet  
Power supply

### 3. Procedure

Observe the orientation of the compasses, then turn on the power supply and observe the orientation of the compasses.

Sketch the compasses. What does this indicate about the direction of the magnetic field surrounding the wire? Map the direction of the magnetic field lines on your paper. Do the compasses point toward or away from a “North” pole? Be sure to de-energize the circuit when complete.

## **5. Energized Solenoid with Soft Iron Core**

### 1. Introduction

Current passing through the coils of a solenoid develop a magnetic field within the hollow core of the solenoid. Examine what happens to the iron rod.

### 2. Equipment

Solenoid  
Power supply  
Iron core small enough to fit within Solenoid  
2 patch cords

### 3. Procedure

Connect patch cords to the power supply and the solenoid. Set the voltage on the power supply to 5V and turn on the power supply. Place the iron rod just inside the hole and let it go, it should be attracted into the hole.

Describe what is happening and sketch the setup. 4B students, draw the magnetic field using the RH rule.

## **6. Electron Beam and Magnetic Force Interaction**

### 1. Introduction

Moving charges are influenced by the presence of magnetic forces. Examine this interaction using an oscilloscope and a permanent magnet.

### 2. Equipment

Oscilloscope

Magnet

### 3. Procedure

When you turn on an oscilloscope, computer monitor, or TV, electrons exciting the phosphorus molecules in a screen behind the glass produce the picture that you see. In an oscilloscope, the phenomenon is rather simple. A single beam of electrons is emitted onto a phosphorus screen and deflected based upon input by an external device, such as a function generator. This beam consists of moving charges, and as such can be affected by magnetic forces.

Plug in the oscilloscope and turn it on. Under the HORIZONTAL section, set the knob marked SEC/DIV to X-Y. You should see a dot appear on the screen. Using a permanent magnet, move the dot around on the screen. Take care not to touch the magnet to the screen because you may end up scratching the screen.

Sketch what is happening here. Does the direction of the deflection change if you use different poles of the magnet.

## **7. Magnetic Force on a Current Carrying Wire**

Using the swinging wire apparatus, connect the leads of the wire to two dry cells wired in series. Note the displacement of the wire. Why does this occur? Reverse the polarity of the leads. Does this change anything? Record your results. Be sure to de-energize the circuit when complete.

## **8. DC Motor**

Connect the leads of the St. Louis motor to a de-energized power supply. Starting on the 0-18V setting, turn the course voltage to maximum, and turn the current to minimum. Switch on the power supply. Slowly increase the current until the motor begins to turn.

- a. What is the correlation between current supply and motor speed?
- b. De-energize the power supply, and reverse the leads. Does this affect the direction of rotation?
- c. Why do the brushes spark for brief periods during rotation?
- d. Are the brushes reversing the direction of current through the stator (fixed electromagnets), rotor (rotating electromagnets), or both?
- e. Record your results, and summarize the operation of a DC Brush motor.
- f. Be sure to de-energize the power supply when complete.

### **9. E/M Induction**

Connect a hollow coil of wire to a galvanometer. Generate an electrical current by moving a permanent magnet in and out of the coil of wire. Also try moving the coil while holding the magnet still. Is the same effect achieved? How do you vary the amplitude of the current? Record your results.

### **10. Generator**

Connect the Cowan Dynamo (hand crank generator) to a galvanometer. Experiment with generating pulsed direct current and alternating current, by moving the brushes. Why does the direct current pulsate? What is the relationship between the rotation of the handle and the frequency of the alternating current? Record your results.

### **11. Transformer**

Connect the DC power supply to outer coil connect galvanometer to inner coil; note surge of current through galvanometer when power supply is turned on or off; note effect of metal core.

### **12. Loudspeaker**

Examine the large loudspeaker. Explain how the frequency generator causes linear motion in the loudspeaker. It may be helpful to set the frequency at 1-5Hz. Does the loudspeaker act as a generator or a motor in this instance? Knowing this, what is the fundamental difference between a loudspeaker and a simple microphone? Record your results.

### **13. Big A.C. Coil**

Examine the construction of the large alternating current coil, and the properties of the ring. Why does the coil cause the ring to fly off? Be cautious of alternating current. Record your results.

### **14. Doorbell**

Connect the “doorbell” apparatus to a battery. Explain the oscillating motion. How does a direct current battery allow the armature to switch directions so quickly, without brushes? Also try operating the apparatus with a hand crank generator. Record your results.

### **15. Oscilloscope**

Connect a signal generator to the vertical input of an oscilloscope. Adjust the signal generator to a sine wave, starting with a very low frequency of 1-2Hz. Also adjust the Horizontal Division on the O-scope until a familiar sine wave is displayed.

- a. A cathode ray tube works by deflecting a stream of electrons (from the electron gun) with a set of high voltage deflector plates. The potential on these plates can vary in both amplitude and sign (+ or -), thereby changing the electric and magnetic field. The deflected electrons excite a phosphorescent screen, causing an image to be formed.
- b. Knowing this, how does the signal generator “control” the O-scope? In this setup, does the signal generator affect the horizontal deflector plates, or the vertical deflector plates?
- c. What does the Horizontal Division setting change on the O-scope? How does it achieve this?
- d. How would a pure direct current signal be displayed on the O-scope?
- e. Record your results.

## 16. Hand Crank Generator and Light Bulbs

Connect the small hand crank generator to a lamp. Turn the crank to light the lamp. Remove the lamp and try it again. Explain the difference you experience. Record your results.

## 17. A. C. Electric Motor

Analyze the alternating current electric motor making sure you understand how it runs. What is the relationship between the frequency of the signal generator and the frequency of the rotating armature?

## 18. Eddy Currents

### Swinging Aluminum Combs

- Connect the **comb** to the pivot and release it from a height to swing between the permanent magnets. Note the speed of the comb as it passes between the magnets.
- Connect the **closed comb** (the one with the loop around the perimeter) to the pivot and release it from the same height as in part (a) letting it swing between the permanent magnets again. Note the speed of the closed comb as it passes between the magnets.
- Connect the **solid comb** to the pivot and release it from the same height as in part (a) letting it swing between the permanent magnets again. Note the speed of the solid comb as it passes between the magnets.
- Is the stationary aluminum attracted to one of the magnets? Why or why not?
- Rank the three combs according to their speeds as they pass between the magnets for the first time and explain why the variation in damping is observed.

### Magnet on Incline

- Release a magnet from rest so it slides down an angled **non-conducting sheet** (let magnet slide, not roll to get best results) Note the speed of the magnet during the motion.
- Release the magnet from rest so it slides down an angled **conducting sheet** (let magnet slide, not roll to get best results) Note the speed of the magnet during the motion.
- Which is the lower speed and why.

## 19. Pipe w/ WEIGHTS

Drop the two taped weights through the vertical aluminum pipe.

- What are the properties of aluminum?
- Explain why one of the weights takes longer to fall than the other.
- Draw a free-body diagram (FBD) of the slower weight as it is falling.
- Can the slower weight ever come to rest in the vertical pipe? Why or why not.

## 20. PIPE w/ weights

- Read the scale that is suspending the pipe.
- Drop the magnet provided through the vertical aluminum pipe, while noting the reading on the scale.
- Explain your observations.
- Draw a FBD of the pipe as the weight is falling.
- Is there any relationship between the forces in the FBD of the falling weight in 19 c (above) and the forces in the FBD of the pipe? If so, what?