DEMOS ILLUSTRATING PRINCIPLES OF MAGNETISM AND ELECTROMAGNETIC INDUCTION

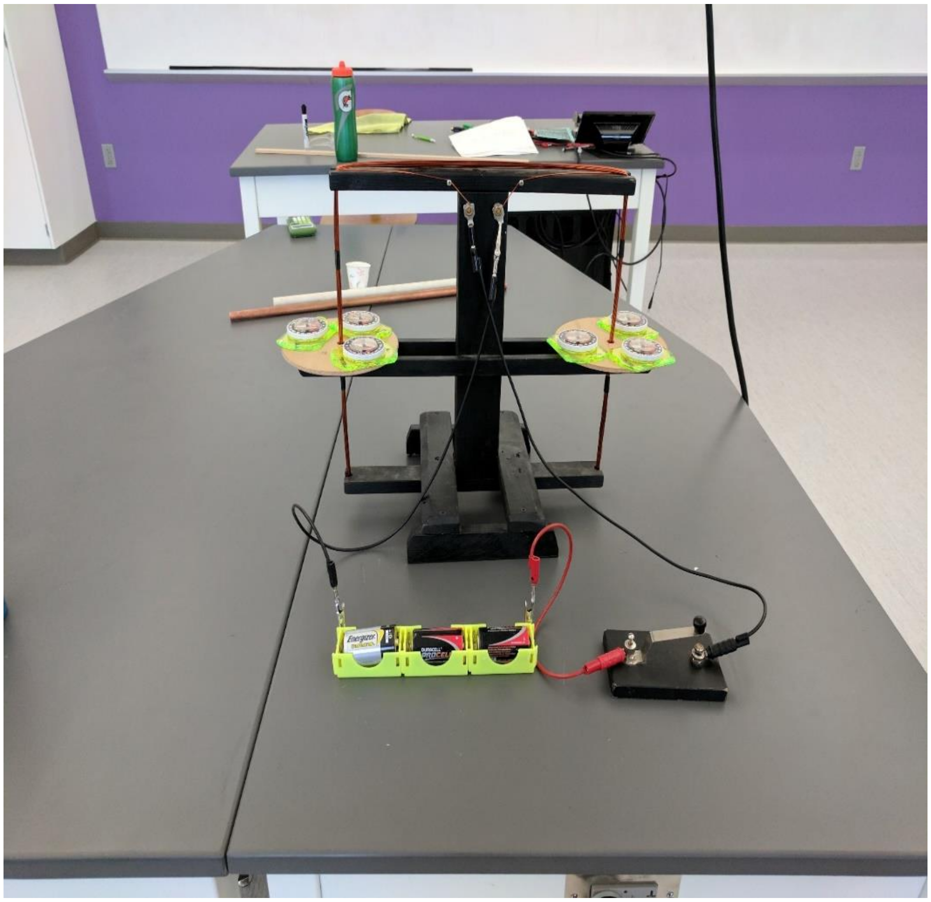
Magnetic Principles

Introduction: In this laboratory exercise you will review phenomena that are a direct consequence of basic electromagnetic principles. Each demonstration was chosen to illustrate one fundamental principle. Several questions accompany each demonstration. To obtain the maximum benefit of this lab, read all the questions that accompany each demonstration first, so you will focus on the fundamental principle that it illustrates. Then, answer the "Prediction" questions before activating the apparatus. Answer remaining questions after activating and observing the results.

The main objective in this lab is to observe all phenomena and record your observations carefully. Your TA will review the principles behind the various demonstrations and then allow you to explore them. You should take good notes since you should be able to explain how these demos work for the final exam.

DEMONSTRATION #1

MAGNETIC FIELD AROUND A STRAIGHT WIRE



Observe the circuit, polarity, and direction that the compass needles point before pressing the switch to put current through the apparatus.

Prediction: What direction do you expect the compass needles to point when the current is turned on?

Activate the circuit. Was your prediction correct? Why or why not?

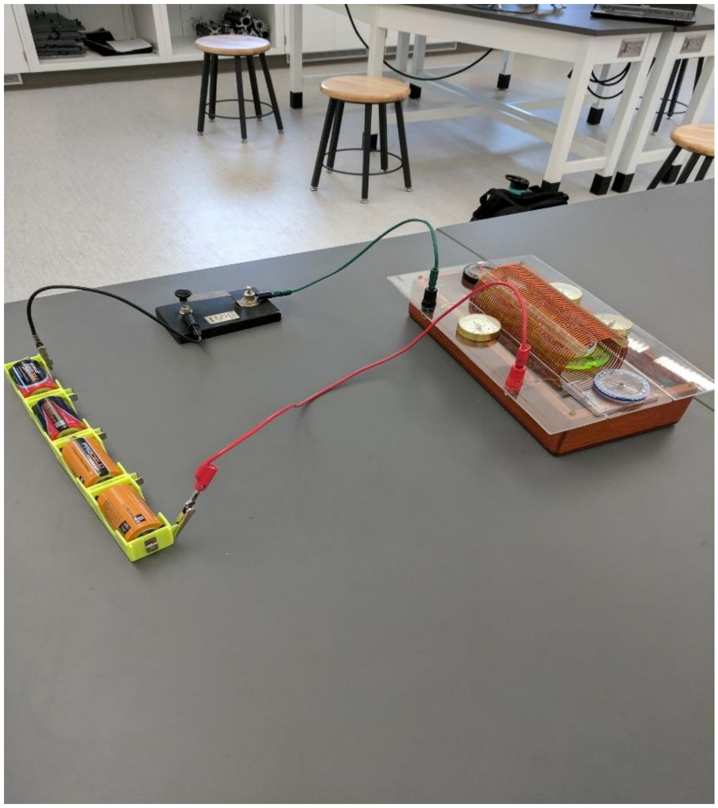
Prediction: What direction would you expect the compass needles to point when the current is turned on, if you reverse the direction of the current?

Switch the wires to reverse the current. Activate the circuit. Was your prediction correct? Why or why not?

Draw and label clearly a simple diagram showing current through the wire and the direction of the magnetic field that results.

DEMONSTRATION #2

MAGNETIC FIELD THROUGH A COIL



Observe the circuit, polarity, and direction that the compass needles point before pressing the switch to put current through the apparatus.

Prediction: What direction do you expect the compass needles to point when the current is turned on?

Activate the circuit. Was your prediction correct? Why or why not? (You may want to move a compass around the coil to determine the direction of the magnetic field around the coil to help in drawing the diagram asked for below.)

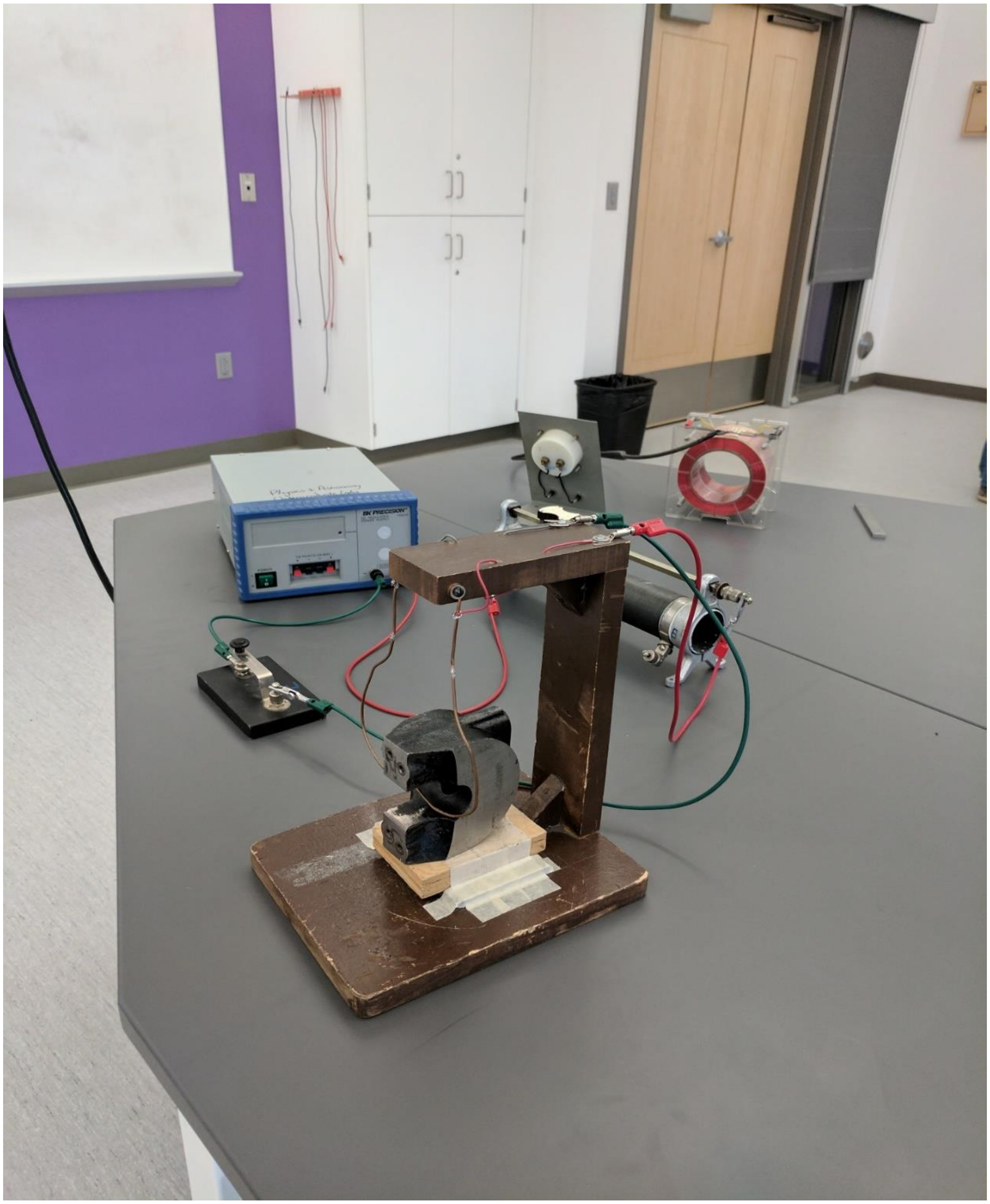
Prediction: What direction would you expect the compass needles to point when the current is turned on, if you reverse the direction of the current?

Switch the wires to reverse the current. Activate the circuit. Was your prediction correct? Why or why not?

Draw and label clearly a simple diagram showing current through the coil and the direction of the magnetic field. Be sure to indicate the field directions through the coil as well as outside of it.

DEMONSTRATION #3

MAGNETIC FIELD ON A CURRENT-CARRYING WIRE



Observe the circuit, polarity, and direction of the magnetic field before pressing the switch to put current through the apparatus.

Prediction: What direction do you expect the wire to move when the current is turned on?

Activate the circuit. Was your prediction correct? Why or why not?

Prediction: What direction would you expect the wire to move when the current is turned on, if you reverse the direction of the current?

Switch the wires to reverse the current. Activate the circuit. Was your prediction correct? Why or why not?

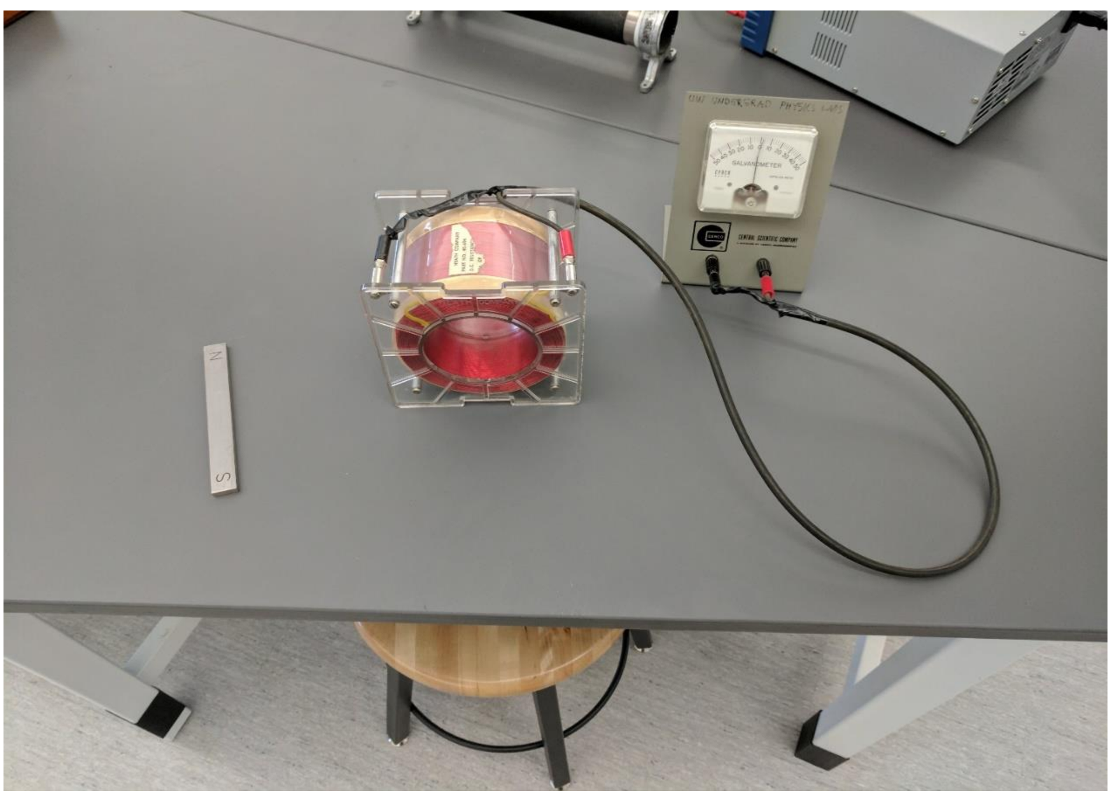
Prediction: What direction would you expect the wire to move when the current is turned on, if you reverse the North and South poles of the magnet?

Reverse the North and South poles of the magnet. Activate the circuit. Was your prediction correct? Why or why not?

Draw and label clearly a simple diagram showing current through the wire, the direction of the magnetic field, and the direction of the force on the wire.

DEMONSTRATION #4

INDUCED CURRENT IN A COIL BY A BAR MAGNET



Observe the circuit, noting the direction of the windings in the coil.

Prediction: What direction do you expect the needle to deflect when you move the South Pole of the bar magnet toward the coil? When you move it away?

Move the South Pole toward and away from the coil. Were your predictions correct? Why or why not?

Prediction: What direction do you expect the needle to deflect when you move the North Pole of the bar magnet toward the coil? When you move it away?

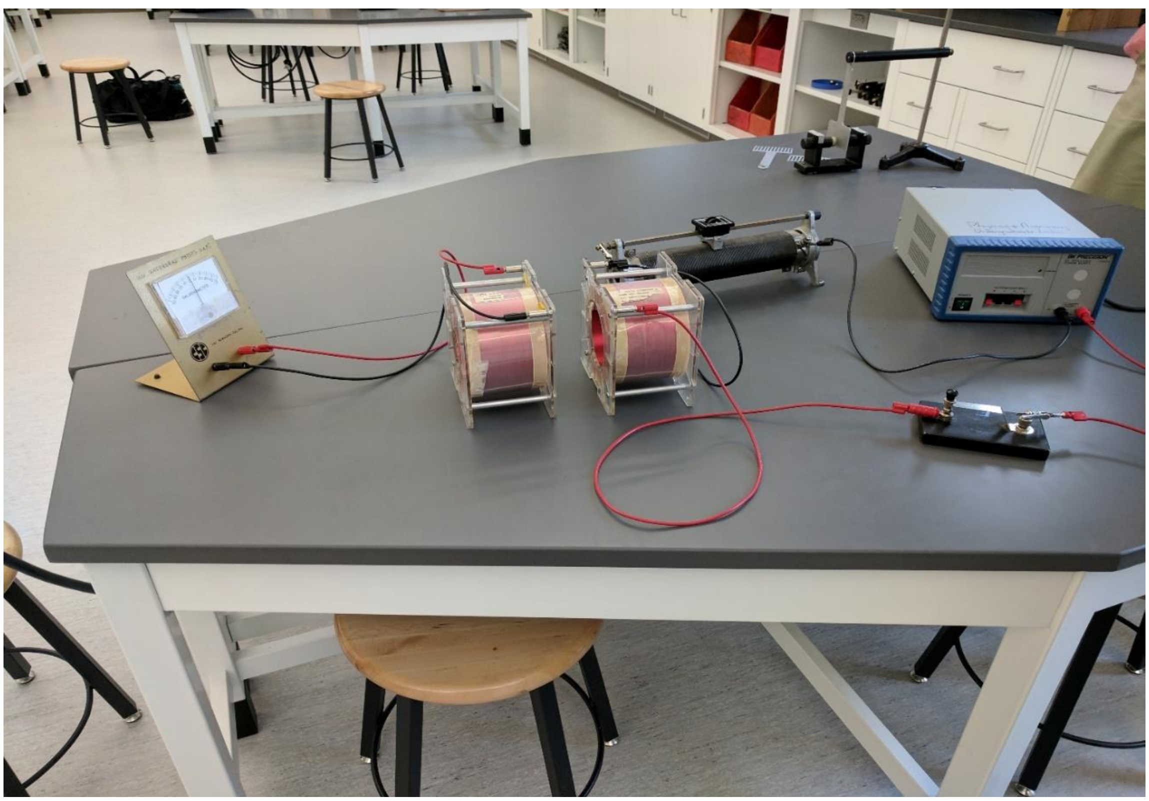
Move the South Pole toward and away from the coil. Were your predictions correct? Why or why not?

Describe the needle deflection if you hold the magnet motionless near the coil.

What creates maximum deflection of the galvanometer? Minimum?

DEMONSTRATION #5

INDUCED CURRENT IN A COIL BY ANOTHER COIL



Observe the circuits, noting the direction of the windings in the coils. The primary coil is the one connected to the power supply. The secondary coil is connected to the galvanometer. Note that nothing connects the two coils.

Prediction: What direction do you expect the needle in the galvanometer connected to the secondary coil to deflect when you turn on the current in the primary coil? When you open the switch and turn the current off?

Turn on the current in the primary coil. Were your predictions correct? Why or why not?

Prediction: What happens to the deflection of the needle in the galvanometer if you move the coils further apart? Closer together?

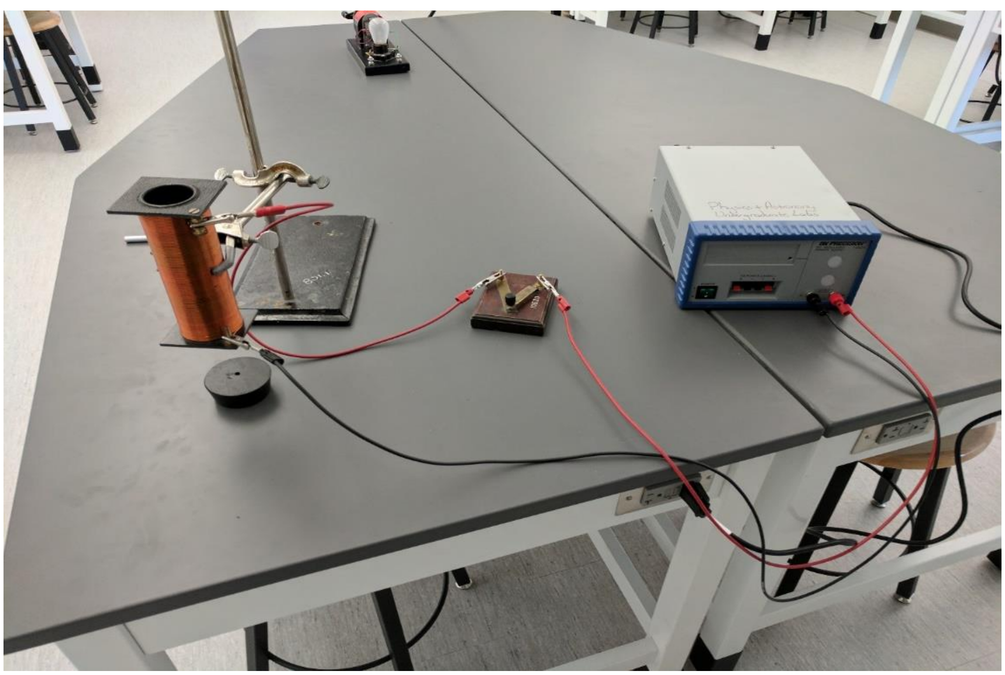
Move the coils and close and open the switch. Were your predictions correct? Why or why not?

Describe the needle deflection as you hold the switch closed.

With the switch open, move a bar magnet back and forth in the primary coil. Does anything happen in the secondary circuit?

DEMONSTRATION #6

SUCTION COIL



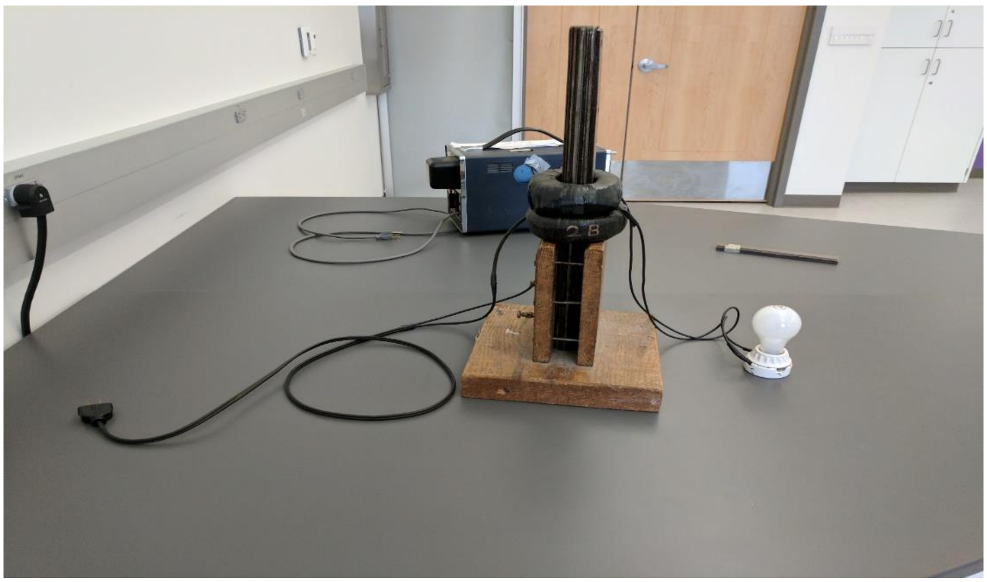
Two cylinders, one steel (steel contains mostly iron) and one of aluminum, rest on the table. They are partially inserted into a coil of wire.

Prediction: What do you expect to happen when you close the switch? When you open it?

Close the switch. Were your predictions correct? Why or why not?

DEMONSTRATION #7

ALTERNATING CURRENT (AC) INDUCTION



Plug the cord into the 115 volt AC socket. What happens? Why?

Prediction: If the upper coil is slid upward, what will happen?

Slide the coil upward. Were your predictions correct? Why or why not?

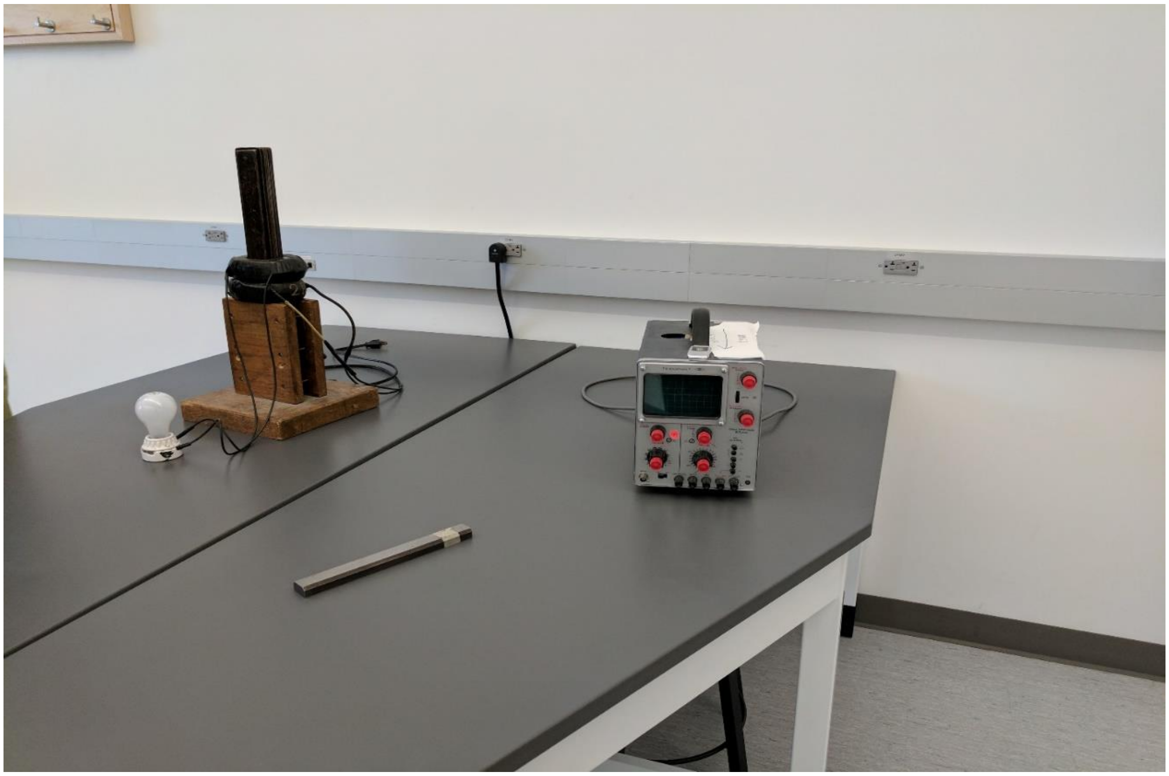
The center iron core intensifies the magnetic field.

Prediction: Would the bottom coil still induce a current in the upper that would light the bulb if the coils were slid off the iron core?

Carefully slide the coils off the iron core. Were your predictions correct? Why or why not? Does the bulb light as brightly as when the coils were mounted on the iron core?

DEMONSTRATION #8

ELECTRON BEAM DEFLECTION IN A MAGNETIC FIELD



Demonstration #8

Electron Beam Deflection in a Magnetic Field

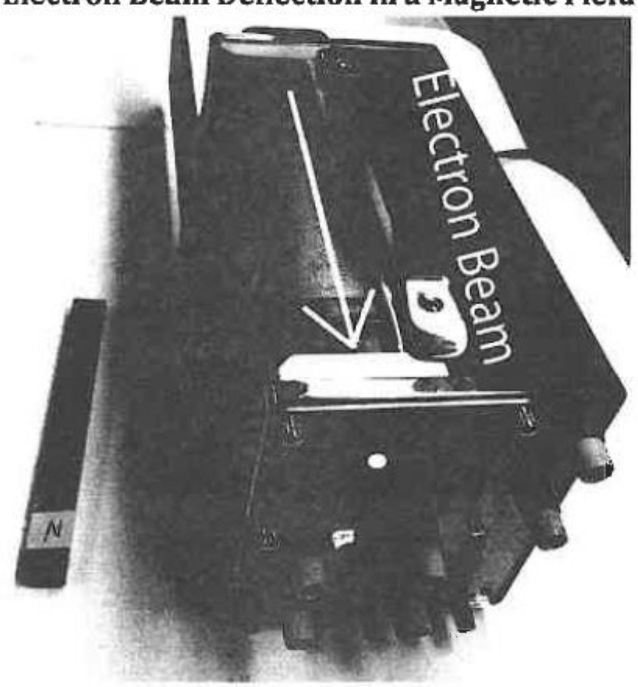


Figure 8: An oscilloscope with the sides cut away to show the tube carrying the electron beam to the screen.

CAUTION: Do not stick your fingers into the holes cut into the top and side of this apparatus. This is an old oscilloscope that runs on high voltage, and contact with the interior components could result in injury!

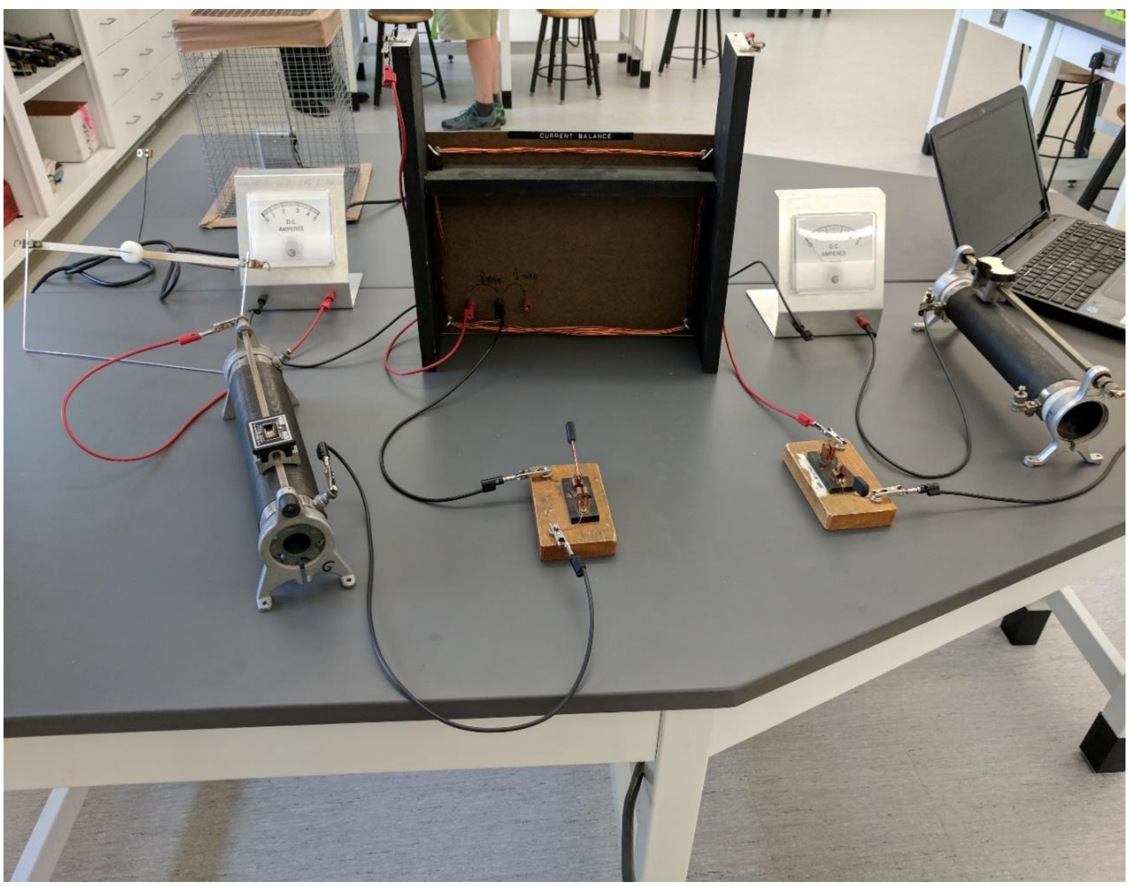
This apparatus has an internal beam of electrons that are accelerated down a tube until they strike the screen and fluoresce, appearing as a bright dot. Electron beams can be affected by magnetic fields.

1. Predict what will happen to the dot on the screen if you place the North Pole of the magnet into the hole at the top of the apparatus. Record your prediction.

2. Were you correct? If not, discuss with your group members and determine why you were wrong.
3. Make a new prediction of what would happen if you placed the South Pole of the magnet into the side hole in the apparatus.
4. Test the new prediction.
5. Test the other configurations the magnet with the electron beam, until you are confident you can predict the direction of deflection of the electron beam for all configurations.

DEMONSTRATION #9

FORCE BETWEEN TWO CURRENT CARRYING WIRES



The purpose of this exercise is to predict and observe the direction of the force on the moveable wire produced by the fixed-wire coil. The photo shows the Fixed-Wire Box Assembly with the Pivoting Magnetic-Balance Assembly, flanked by two 0 – 5 Amp Ammeters. Two Variable Slide Resistors and two Knife Switch Assemblies sit in front of the ammeters.

Caution: Do not exceed 4.0 Amps in either circuit, as the resistor coils may overheat. Adjust the variable slide resistors to control the current. You may need to be close to that value to observe the attraction or repulsion between the wires. **Open both knife switches anytime you are not observing the circuits.**

Carefully slide the pivoting wire assembly so that it is parallel to, and within about 1.0 – 2.0 cm of the fixed coil of wires. Observe the direction of the current through the bottom portion of the fixed coil of wires. Determine the direction of the magnetic field it produces at the position of the bottom portion of the pivoting wire. Determine the direction of the force created on the bottom portion of the pivoting wire. Record your predictions below, close both knife switches, and observe the motion of the pivoting wire.

Predicted direction of the magnetic field (circle one): up down left right away toward
as you sit in front of the Fixed-Wire Assembly.

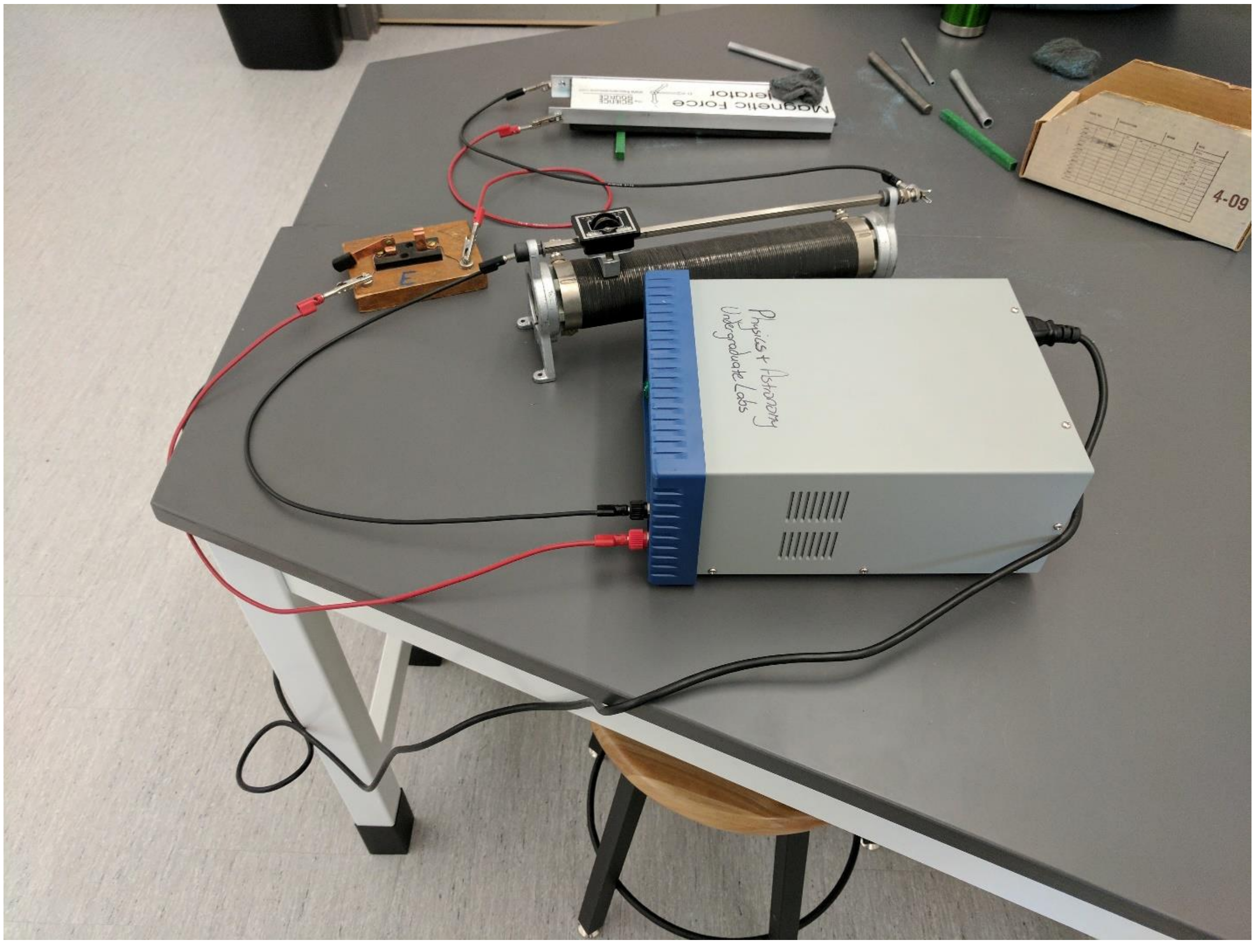
Predicted direction of the force on the pivoting wire (circle one): attraction repulsion
with regards to the Fixed-Wire Assembly.

Observed direction of the force on the pivoting wire (circle one): attraction repulsion

If your observed force does not agree with your predicted force, determine why they disagree.

DEMONSTRATION #10

MAGNETIC FORCE ACCELERATOR: THE MODEL "RAIL GUN"



Demonstration #10: Magnetic Force Accelerator (The Model "Rail Gun")

PURPOSE: To observe the force on a current-carrying tube in a fixed magnetic field.

Figure 10. The Magnetic Force Accelerator (a model "Rail Gun") is shown above with block under the left end to provide an inclined plane. Electrical terminals on right side would be connected to power supply. Fixed magnets provide a fairly uniform magnetic field directed upwards.

Horizontal Motion:

<u>**Caution**</u>: You may need to adjust the variable slide resistor to increase the current and cause the aluminum tubes to roll. **To avoid overheating of the circuit, open the knife switch anytime you are not observing the motion of the tubes.**

Check that the "Magnetic Force Accelerator" is lying horizontally in the green tray.

Note the direction that the conventional current will flow through one of the tubes placed on the parallel rails of the "Magnetic Force Accelerator."

The magnetic field from the permanent magnets inside the accelerator is directed upward.

Predict which direction one of the aluminum tubes will roll when placed on the apparatus at right angles to the metal tracks.

Observe the direction the aluminum tube rolls when you place it on the tracks. Does your observation agree with your prediction? If not, determine why.

Which of the three pieces of aluminum tubing draws the most current when it moves along the rails?

Do the pieces of tubing move at a constant velocity or do they accelerate?

Motion on an incline:

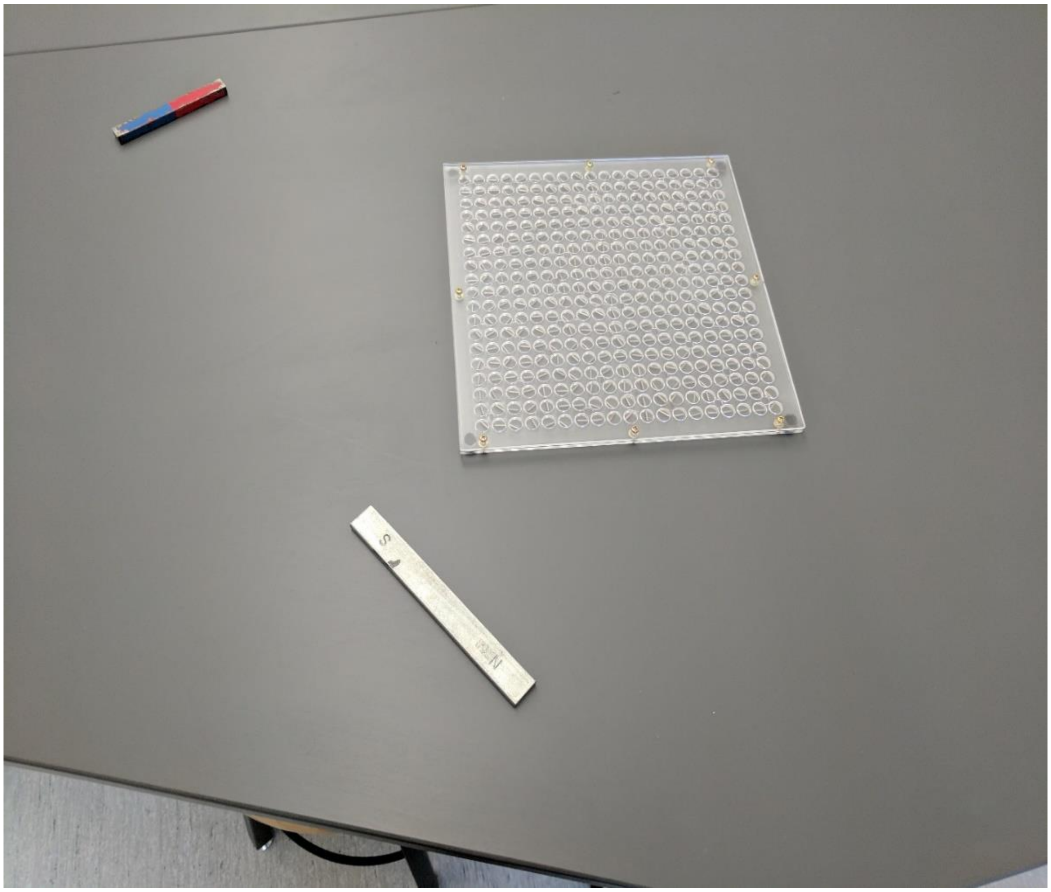
Place the painted wooden stick under the end of the accelerator away from the terminals.

Observe the motion of each of the three tubes. You may need to lightly prod a tube to set it in motion. Which of the three pieces of aluminum tubing draws the most current when it moves up the inclined rails?

Do the pieces of tubing move at a constant velocity or do they accelerate?

DEMONSTRATION #11 AND #12

THE MAGNETIC FIELD



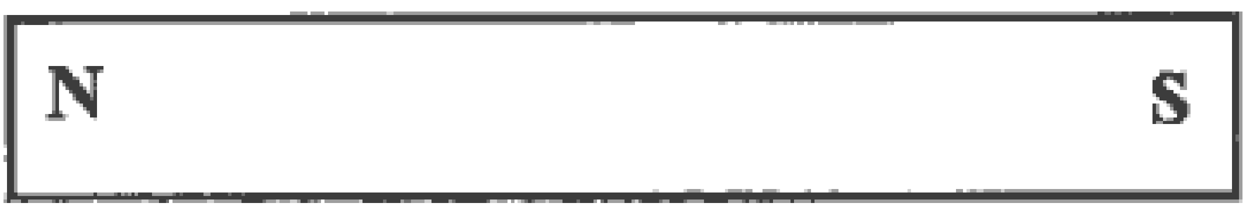
Demonstration #11: The Basic Magnetic Field, Part 1

PURPOSE: To observe with a compass the direction of the magnetic field around a bar magnet.

Bring the compass close to the North end of the bar magnet. Describe the position of the needle of the compass.

Bring the compass close to the South end of the bar magnet. Describe the position of the needle of the compass.

Starting with the compass at the North end of the bar magnet, move it slowly in an arc until it is at the South end of the bar magnet. Do this two or three times in arcs around both sides of the magnet and sketch the field lines below, showing the direction of each field line with arrowheads.



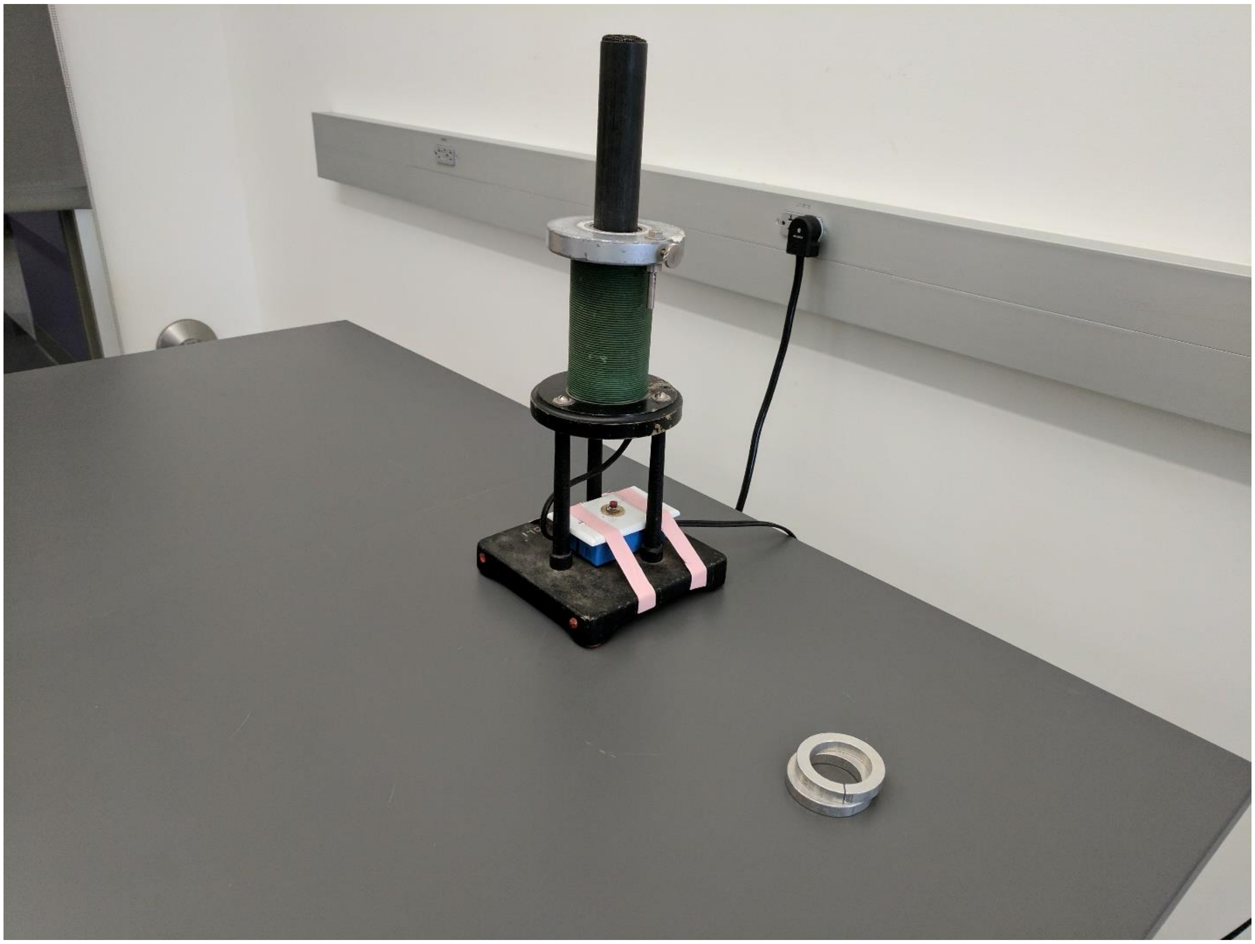
Demonstration #12: The Basic Magnetic Field, Part 2

PURPOSE: To observe the magnetic field around a bar magnet.

Remove the magnet from the plastic container. Shake vigorously until the metallic fibers in the fluid are distributed. Set the plastic container on the table. Replace the magnet. Watch as the fibers outline the magnetic field inside the container.

Repeat, if desired, changing the orientation of the plastic container.

DEMONSTRATION #13
THE RING LAUNCHER



The purpose of this demonstration is to observe the force on a conducting ring when placed in a rapidly changing magnetic field produced by alternating current (ac). The picture above shows a ring launcher with two aluminum rings, one forming a complete cylinder, one split so that it does not form a complete cylinder. The black cylinder emerging from the top of the coils is adjustable in length.

Magnetic induction as a result of alternating current (a.c.) passing through the coil causes a changing magnetic flux through the ring placed on the launcher. The frequency of a.c. in the U.S. is 60 Hz (60 cycles per second), building and collapsing the magnetic field 120 times per second. The induced emf in the ring sets up a current which produces a magnetic field which opposes the field of the coil, resulting in a force that pushes the ring upward.

Caution: Do not look down on the launcher when activating the circuit as some rings may rise more than a meter into the air.

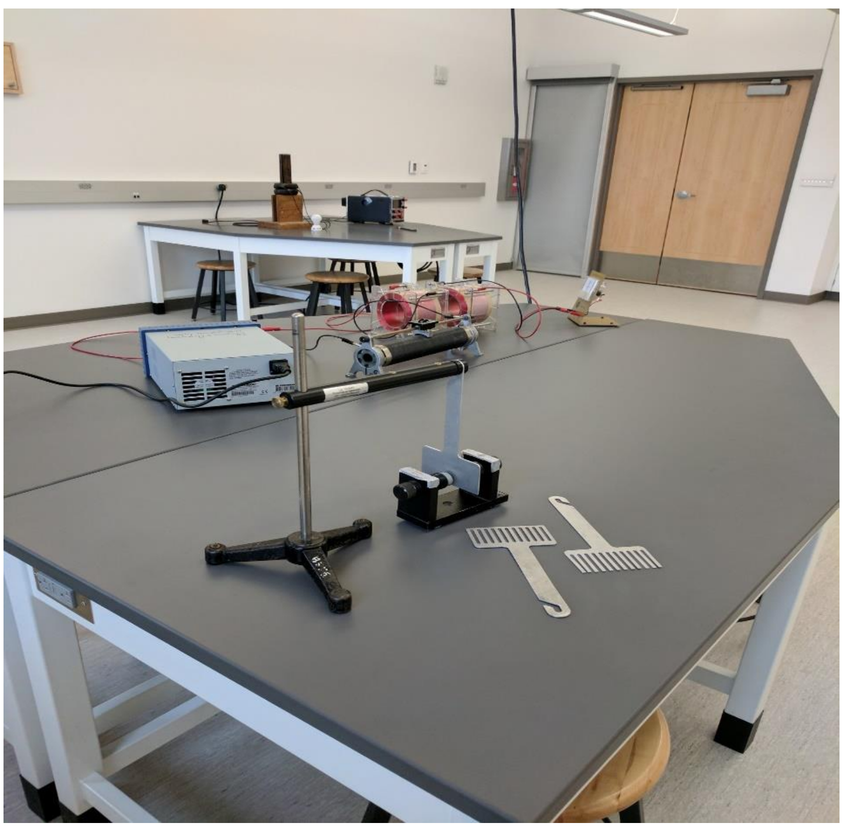
Which rings rise the highest when the magnetic coil is activated by pressing the button?

Which rings rise the least or fail to move at all?

What is the difference between rings that launch and those that do not?

DEMONSTRATION #14

EDDY CURRENTS AND THE MAGNETIC FORCE, PART 1



Demonstration #14: Eddy Currents and Magnetic Force, Part 1

PURPOSE: To observe the forces produced on three different styles of aluminum (non-magnetic) pendulum bobs as they pass through a magnetic field.

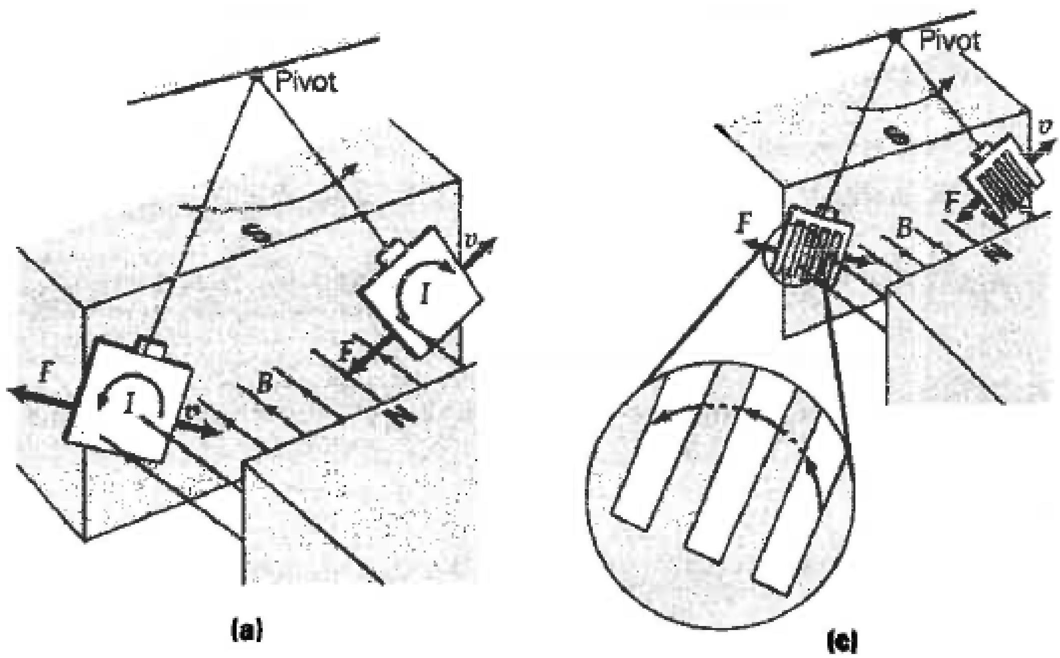


Figure 14. From Figure 20.17 on page 686 in your text, this shows the motion of the solid paddle pendulum bob in (a) and the fully-slotted paddle pendulum bob in (c) as they swing through an external magnetic field. Note the directions and magnitudes of the induced currents and resulting forces on the bobs.

Hang one of the aluminum paddles so that it moves between the poles of the horseshoe magnet with touching either pole. Raise the paddle so that it makes an angle of 60° or more with the vertical and release it. Observe what happens to the paddle as it swings between the poles of the horseshoe magnet.

Which style(s) of paddle continue(s) to swing through the magnetic field between the poles of the horseshoe magnet?

Which style(s) of paddle stop(s) the quickest when reaching the magnetic field between the poles of the horseshoe magnet?

Use your right-hand rule to determine the direction of the force stopping the motion of the paddle in the magnetic field of the horseshoe magnet.

DEMONSTRATION #15

EDDY CURRENTS AND THE MAGNETIC FORCE, PART 2

Demonstration #15: Eddy Currents and Magnetic Force, Part 2

PURPOSE: To observe and compare the forces produced on a magnet dropped through a non-magnetic, conducting tube (copper) with those when the same magnet dropped through a non-magnetic, non-conducting tube (pvc, plastic tube).

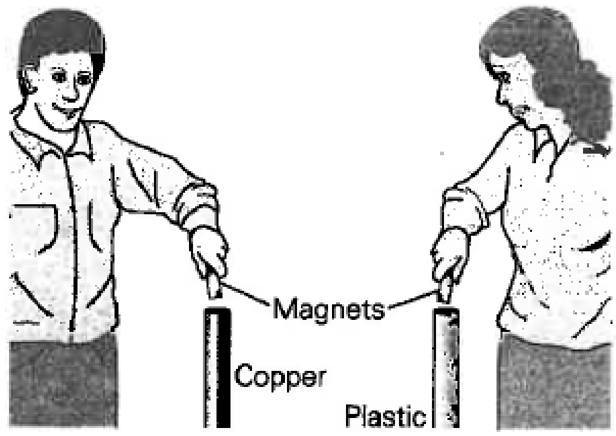


Figure 15. From Figure 20.27, page 696 of your text. In your demonstration you will drop a magnet first through one tube held vertically, then the other and observe the time for the magnet to pass completely through each tube.

Hold one of the tubes as nearly vertical as possible. Release the magnet and determine how long it takes for the magnet to completely pass through the tube. Do the same for the second tube.

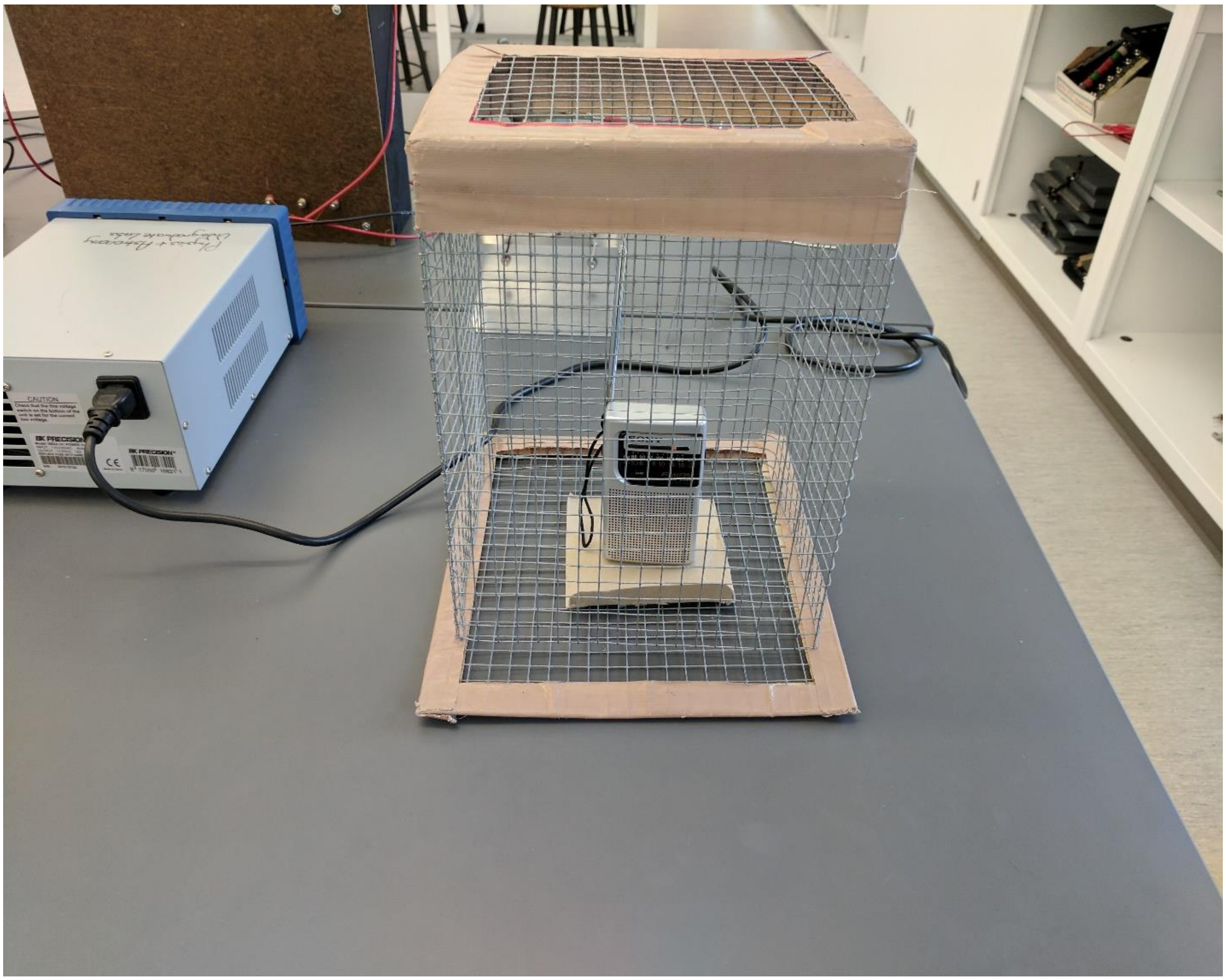
Which tube allows the magnet to fall through it the quickest?

Which tube allows the magnet to fall through it the slowest?

Demonstration #16: The Faraday Cage – Magnetic Shielding

PURPOSE: To observe that a Faraday Cage shields a radio receiver from electromagnetic radiation.

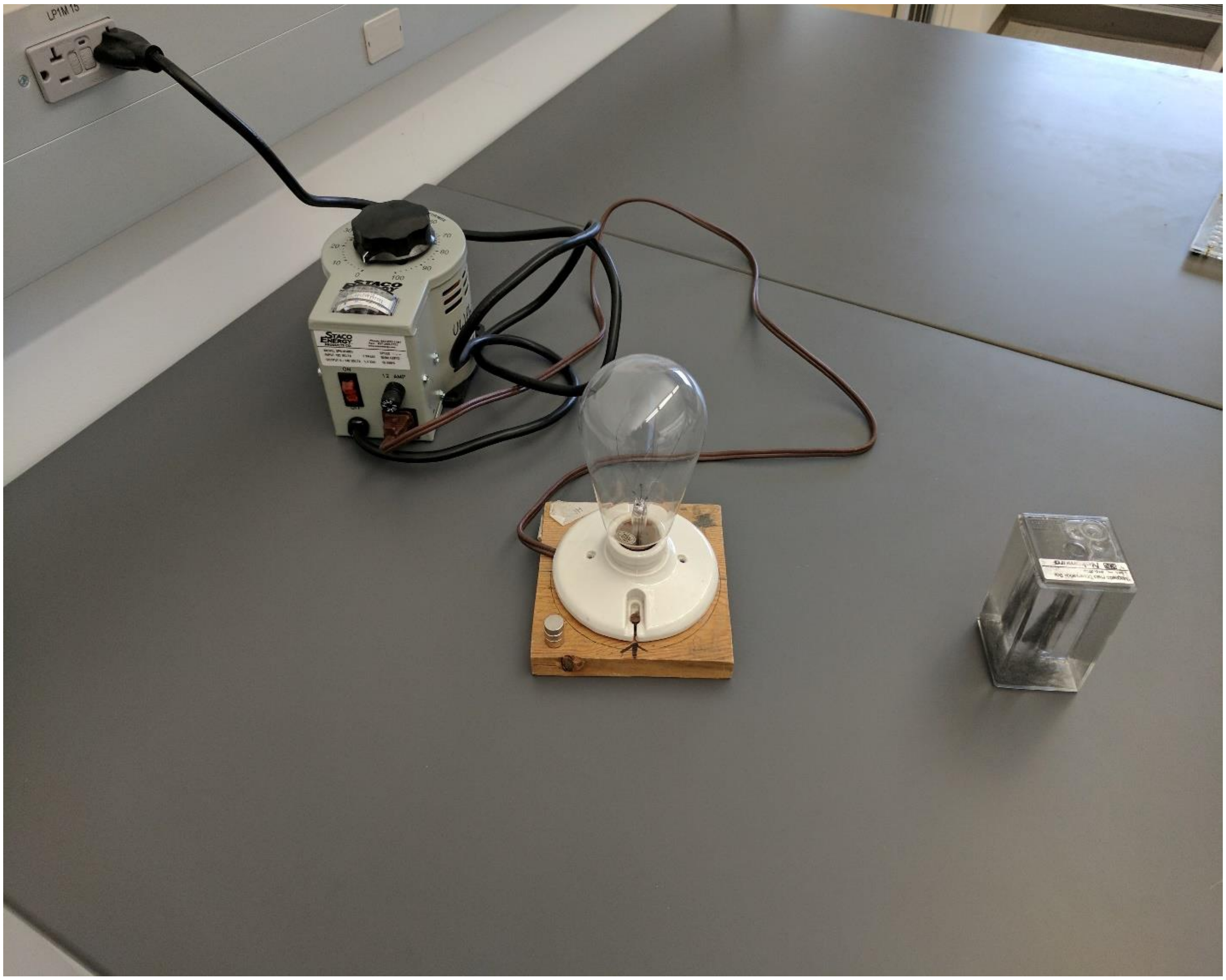
A hollow metal conductor will protect the interior from electric fields. This can be demonstrated by tuning the portable radio to a station at a reasonable volume. Lower it into the Faraday Cage with the antenna below the top of the cage. Replace the top of the cage. What happens to the volume of the radio?



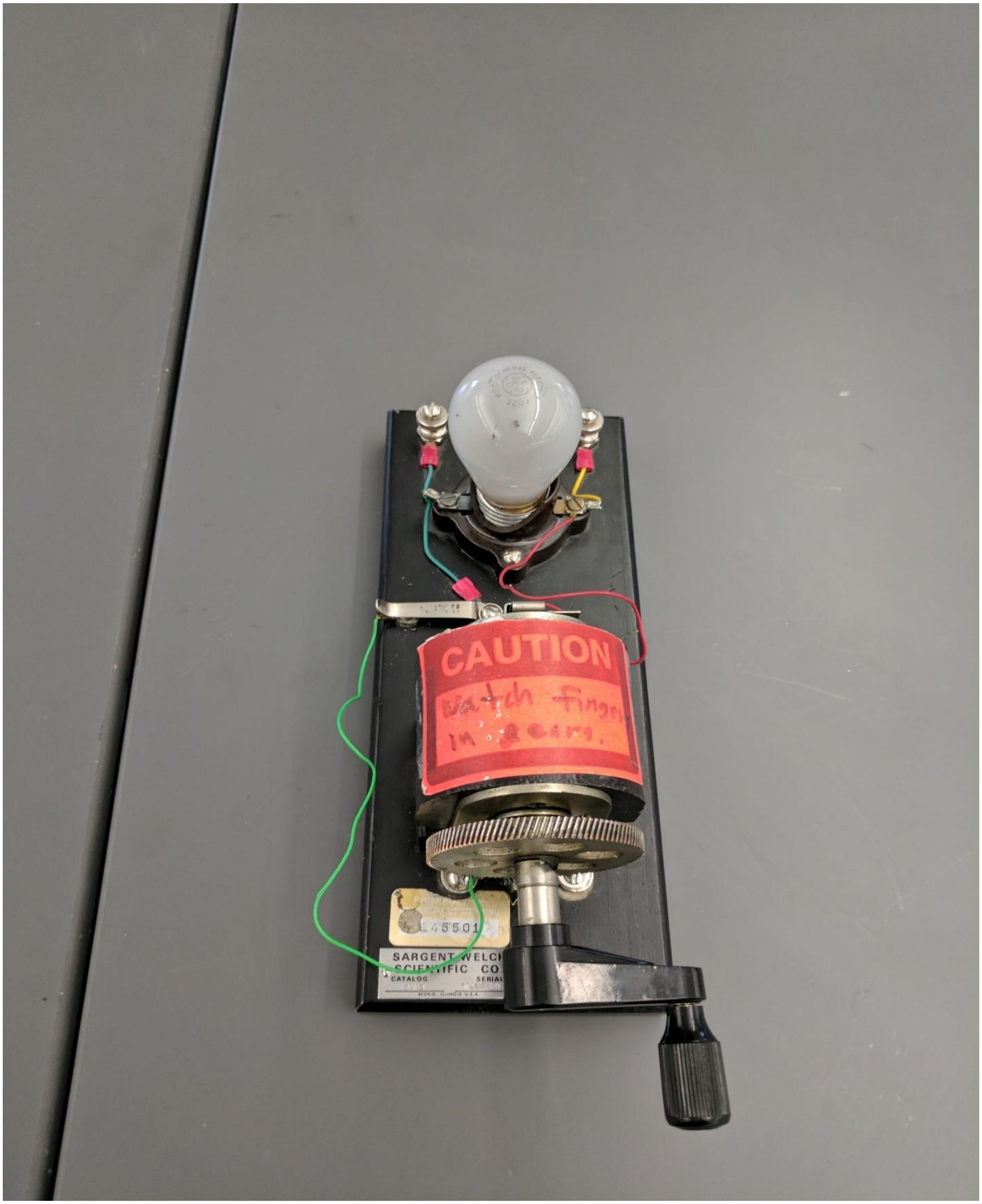
Demonstration #17: The Magnetic Force on a Wire Carrying Alternating Current

PURPOSE: To observe the effects of a magnetic field on a wire carrying alternating current.

Turn on the lamp. Slowly and carefully move the magnet near the lamp. What happens to the filament of the lamp as the magnet is moved around the lamp?

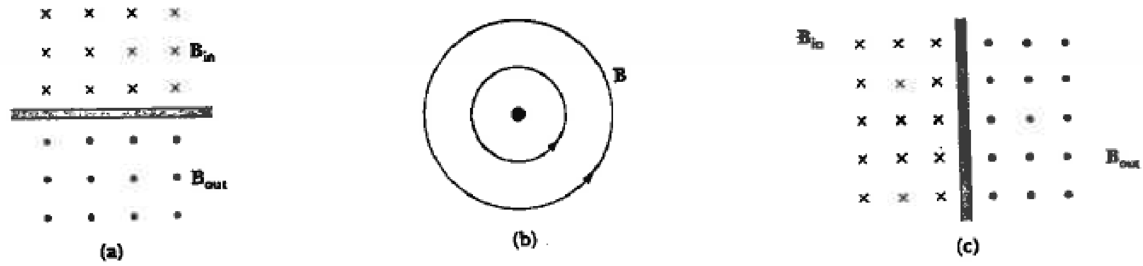


DEMONSTRATION #18
HAND CRANK GENERATOR



QUESTIONS:

Given the figures below, determine the direction of the current in the wire to produce the magnetic field in the direction shown.



1. The direction of the current in figure (a) above is __________.

   a. Into the page
   b. Out of the page
   c. Upward
   d. Downward
   e. Toward the right
   f. Toward the left

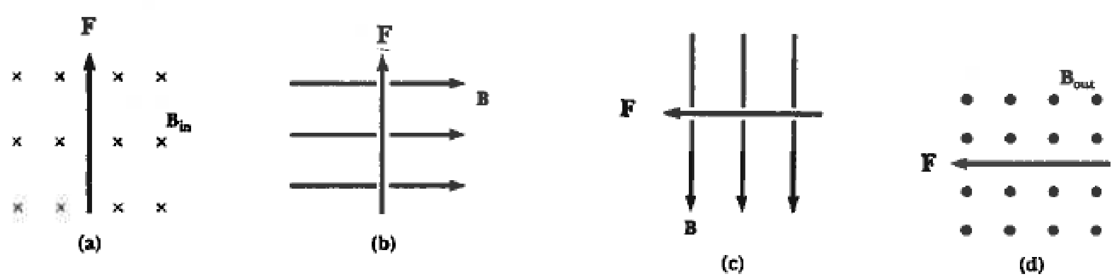
2. The direction of the current in figure (b) above is __________.

   a. Into the page
   b. Out of the page
   c. Upward
   d. Downward
   e. Toward the right
   f. Toward the left

3. The direction of the current in figure (c) above is __________.

   a. Into the page
   b. Out of the page
   c. Upward
   d. Downward
   e. Toward the right
   f. Toward the left

The figures below show the direction of the magnetic field and the direction of the force resulting on a proton moving through the field. Determine the direction of the particle as it enters the field to produce the force shown.



4. The direction of the proton in figure (a) above is __________.

a. Into the page
b. Out of the page
c. Upward
d. Downward
e. Toward the right
f. Toward the left

5. The direction of the proton in figure (b) above is __________.

a. Into the page
b. Out of the page
c. Upward
d. Downward
e. Toward the right
f. Toward the left

6. The direction of the proton in figure (c) above is __________.

a. Into the page
b. Out of the page
c. Upward
d. Downward
e. Toward the right
f. Toward the left

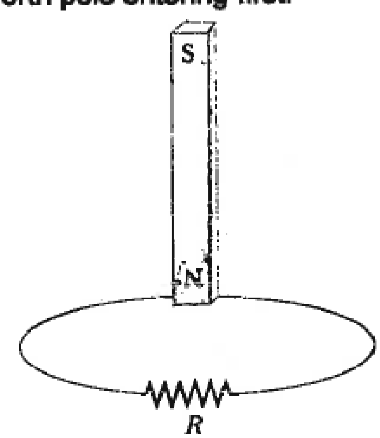
7. The direction of the proton in figure (d) above is __________.

a. Into the page
b. Out of the page
c. Upward
d. Downward
e. Toward the right
f. Toward the left

8. If the particle were an electron in figure (c) above, its direction of movement is ________.

g. Into the page
h. Out of the page
i. Upward
j. Downward
k. Toward the right
l. Toward the left

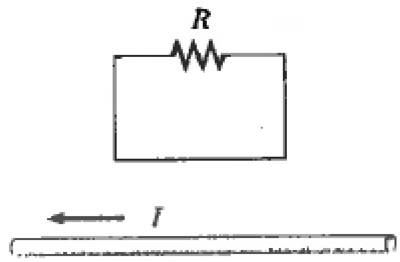
Consider the bar magnet shown in the figure below. It is falling through the loop of wire with a constant velocity and with the north pole entering first.



9. The current moving through the resistor will be ______.

a. from left to right
b. from right to left
c. zero

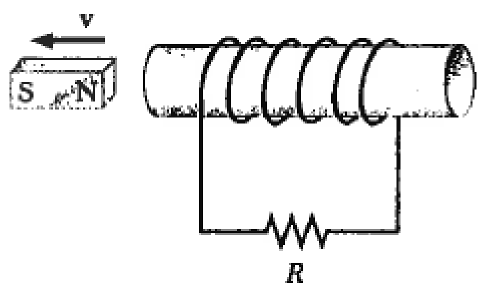
Consider the figure below.



10. What is the direction of the current induced in the resistor when the current in the long straight wire in the figure above is rapidly reduced to zero?

a. from left to right
b. from right to left
c. zero

Consider the figure below.



11. What is the direction of the current induced in the resistor when the magnet is moved to the left?

a. from left to right
b. from right to left
c. zero

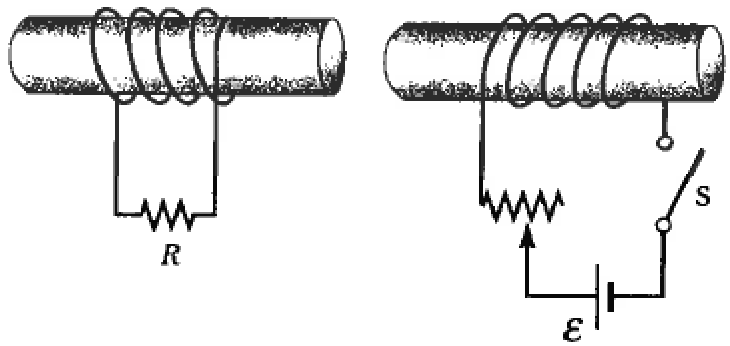
12. What is the direction of the current through the resistor when the magnet is moved to the right?

a. from left to right
b. from right to left
c. zero

13. What is the direction of the current through the resistor when the magnet is held stationary?

a. from left to right
b. from right to left
c. zero

Consider the figure below.



14. What is the direction of the current induced in the resistor when switch is closed?

a. from left to right

b. from right to left

c. zero