Chapter 36 & 37: **Magnetism**

Text:

Chapter 36
Think and Explain: 1, 2, 4, 5
Think and Solve: ---

Chapter 37
Think and Explain: ---
Think and Solve: ---

Vocabulary:
magnetic pole, magnetic field, magnetic field lines, magnetic domains, electromagnet, right hand rule for magnetic field direction, right hand rule for direction of force on a current carrying wire, motor, electromagnetic induction, Faraday's law, generator, direct current, alternating current, transformer

Equations:

$$F_{max} = ILB$$

Key Objectives:

Concepts

- ❑ Like poles repel and unlike poles attract
- ❑ Magnetic poles cannot be isolated
- ❑ Understand what makes magnetic substances magnetic and the role of electrons in creating magnetic fields.
- ❑ State the type(s) of fields the surround a moving charge.
- ❑ Understand the shape and direction of the magnetic field around a current carrying wire.
- ❑ What quantities affect the strength of an electromagnet?
- ❑ Find the direction of force on a current carrying wire placed in a magnetic field.
- ❑ Recognize when the current carrying wire experiences a maximum force or no force.
- ❑ Understand how a motor works to convert electrical energy to mechanical energy.
- ❑ Earth's magnetic poles
- ❑ Be able to relate Faraday's law to the amount of induced current in a wire.
- ❑ Compare motors and generators
- ❑ Understand how a transformer works and how it makes use of electromagnetic induction.
- ❑ E-M waves??

Problem Solving

- ❑ Calculate the maximum force on a current carrying wire in a magnet field.
- ❑ Recognize when the force on a current carrying wire is zero.

Lab 36-1: Magnetism - Part 1

Purpose: To investigate basic magnetism effects.

Materials: 1 ring magnet 2 bar magnets 2 compasses 1 long wire
1 iron fillings 1 solenoid
(paper clips, copper tube, Al foil, pennies, several different nails, silver/gold jewelry you happen to be wearing)

Procedure:

Part 1: What is magnetic?

1. Using the permanent magnets, determine which elements are naturally magnetic. Some of the materials are at your desk, and some have to stay at the teacher's desk.

2. Apart from some rare-earth metals, there are only three elements that are naturally magnetic. What were they?

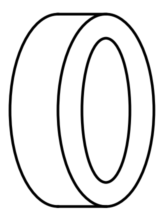
3. Looking at a periodic table, what do you notice about the three elements that are magnetic?

Part 2: How do permanent magnets interact?

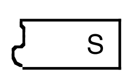
4. Using the two bar magnets, how do the different poles of the magnets interact with each other?

5. If two magnets are repelling each other, what must be true about the poles facing each other? What about if they attract each other?

6. The poles on the ring magnet are not marked. Using a bar magnet, determine how the poles are arranged on the ring magnet and draw your results here.



7. Your teacher has a bar magnet that was broken in half (accidentally.) Bring your compass, and go inspect the broken halves of the magnet. One is marked "N" and the other is marked "S". Do those old marks make sense; is one of them really just a north pole and the other really just a south pole?



Part 3: What is a compass?

8. Your compass needle has a red half and a white half. Leaving the compass and the magnet on the table, slide the compass around the magnet. What do you notice about the compass needle?

Lab 36-1: **Magnetism - Part 1**

9. Try and draw what you just described in the space below.

10. Keeping them on the table, rotate the two compasses around each other. What do you notice about the compass needles?

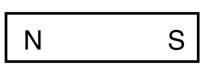
11. Here is a confusing one: A long time ago, compasses were magnetized needles used for navigation. The two ends of the needle were called the "north-seeking pole" and the "south-seeking pole." This has since been shortened to "north pole" and "south pole." Since the north pole of a magnet would point to the earth's North Pole, what kind of magnetic pole is the North Pole?

Part 4: Visualizing the magnetic field.

12. Much like we visualized an electric field with field lines, we can visualize a magnetic field. Thankfully, it is easier to visualize because we can use a compass or iron filings to map out the magnetic field. Both a compass and the iron filings will orient themselves parallel to the magnetic field they are in. You already saw the compass in number 10 above, so here are the iron filings.

13. Use the iron filings to make a sketch of the magnetic field around a single magnet, and then around the ends of two magnets, oriented as shown.

a.



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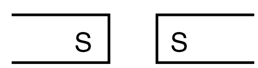

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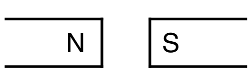

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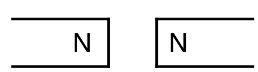


Lab 36-1: Magnetism - Part 2

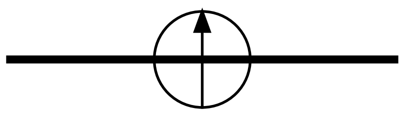
Purpose: To investigate basic electro-magnetic effects.

Materials: 1 bar magnet 1 compasses 1 solenoid 1 long wire 2 short wires

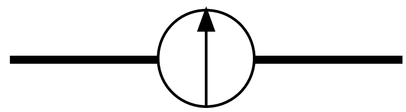
Part 5: The source of the magnetic field.

1. Using a long wire, connect a wire to the power supply (DC) and lay the wire on a compass so that the compass needle is <u>perpendicular</u> to the wire. Slowly turn up the current. Describe what happens to the compass needle as the current increases. Put the compass on the wire and repeat.

wire on compass

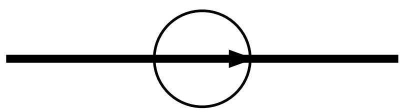


compass on wire

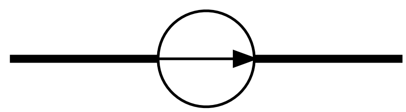


2. Repeat above, but start off with the compass needle parallel to the wire in both cases.

wire on compass



compass on wire



3. (*This is probably set up at the front table*.) Now holding the wire so that is vertical, turn up the current and move the compass around all around the wire in a plane. For each of the situations, sketch the magnetic field around the wire. (NOTE: by definition, current flows from the positive terminal to the negative terminal.)
   a. Current coming OUT of the paper b. Current going INTO the paper

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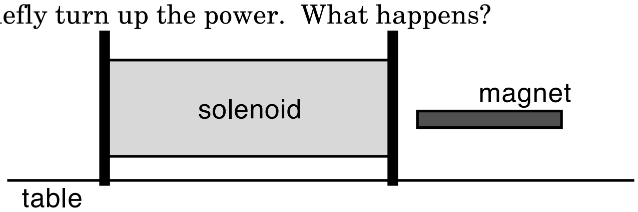
Part 6: Solenoids.

4. Now hook the solenoid up to the power supply (DC side.) Hold some paper clips to the side of the solenoid. Does anything happen? How about if you hold them up to the openings?

5. Hold the bar magnet on the piece of wood and bring it near the opening on the solenoid. Briefly turn up the power. What happens?



Lab 36-1: **Magnetism - Part 2**

6. Try it again, but flip the pole of the magnet. What happens?

7. Flip the connections in the solenoid so the current goes in the opposite direction. Repeat above. What happens?

8. Place the solenoid on its side and turn the power on. Place a compass around the solenoid and record the compass direction all around the solenoid. How does the magnetic field of the solenoid compare to a bar magnet? Sketch it below.

9. So what is a solenoid?

Notes

1. What creates a magnetic field?

2. What kinds of fields surround a stationary electron? What about a moving electron?

3. In an atom, what moving charges create a magnetic field?

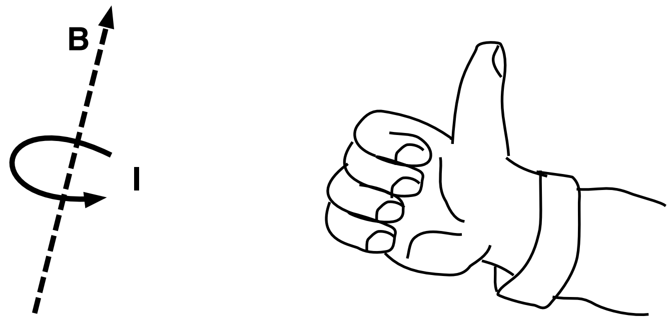
4. What electron motions contribute to an atom's magnetic field?

5. What is a *magnetic domain*?

6. Every atom has lots of electrons moving around a nucleus, so why are most things <u>not</u> magnetic?

Magnetic Field Direction

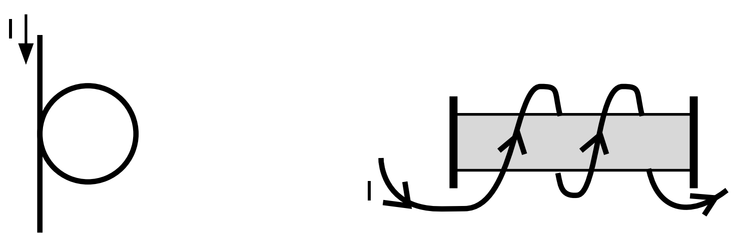
Finding the Magentic Field (B) around a Current (I)
Moving charges create magnetic fields around them. Hopefully you recall that when there is an electric current in a wire, there is a magnetic field that goes around the wire. The magnetic field created is circular and we define the direction with the following:



1. Sketch the magnetic field around a wire carrying a current out of the page (●) and into the page (✕).

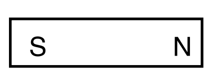
2. Sketch the magnetic field around the following wires:

3. Sketch the magnetic field around the coil and the solenoid below.



4. What happens to the <u>strength</u> of the magnetic field inside the little loop of current from #3?

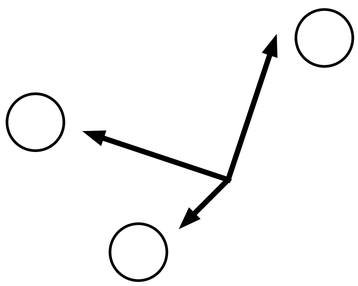
5. Sketch the magnetic field around the bar magnet shown below. (Then label the N and S poles on the solenoid in #3.)

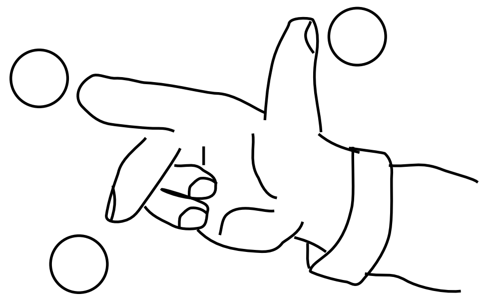


Magnetic Force Direction

Relationship between Force (F), Magnetic Field (B) and Electric Current (I)

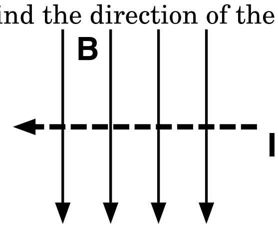
Charges moving in a magnetic field experience a force on them; likewise, an electric current in a magnetic field will experience a force on the current. Mathematically, one finds the force on a current in a magnetic field with something called a *cross product*, which is actually a way of multiplying vectors together and getting a vector for the result. What it means to you is that this is a three-dimensional problem, and Force, Current and Magnetic Field are all perpendicular to each other. It turns out, there is a right hand rule to remember this relationship:





The one tricky thing with this relationship is that if the current and magnetic field are *parallel* to each other, then there is no force. (We will look at how to calculate the amount of force on a current in a magnetic field on another sheet.)

1. Find the direction of the force for the following situations:

a.


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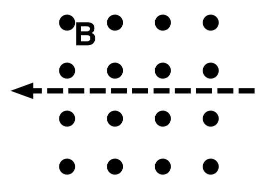

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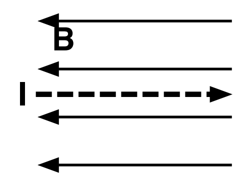

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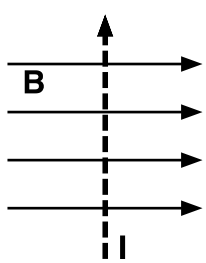

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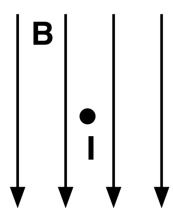

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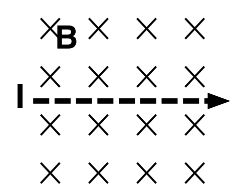

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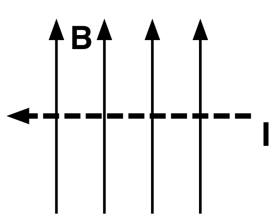

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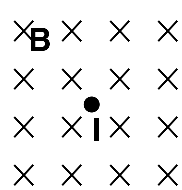

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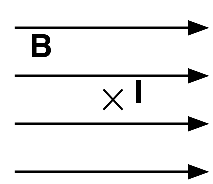
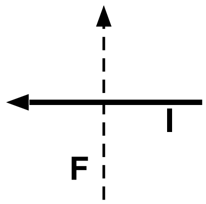
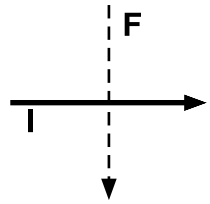
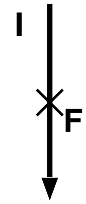


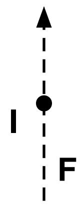
Magnetic Force Direction

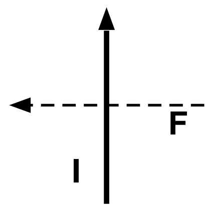
2. Find the direction of the magnetic field that would cause the force for each given current:

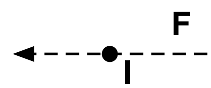
a. 

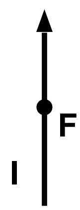
b. 

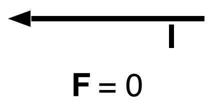
d. 

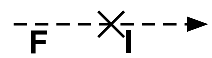
d. 

e. 

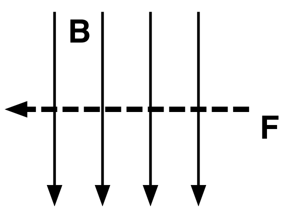
f. 

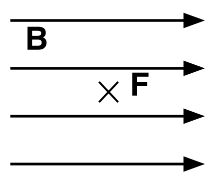
g. 

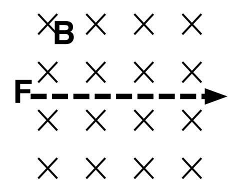
h. 

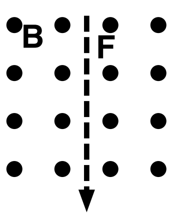
i. 

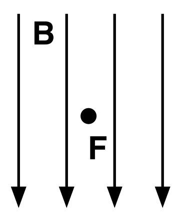
3. Find the current that would experience the force shown in the given magnetic field:

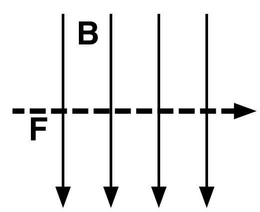
a. 

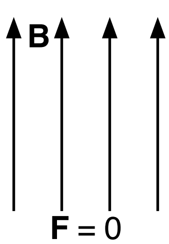
b. 

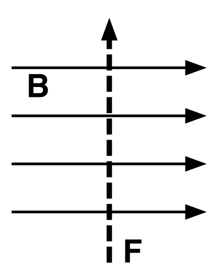
c. 

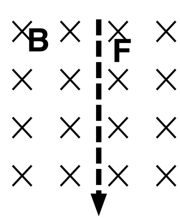
d. 

e. 

f. 

g. 

h. 

i. 

 NAME: ____________________

Force on a Current Carrying Wire

1. What is the force on 1 m of wire carrying a current of 9.8 A perpendicular to a magnetic field of 0.80 T? How would you orient the wire in order for the wire to experience no force?

2. A 1.5 m length of vertical wire has a current of 2 A toward the top of the page. What is the magnitude of the force if the magnetic field of 1 T is directed to the left? What is the direction of the force?

3. A 0.25 m wire carrying 3.4 A of current to the left experiences a 2 N force toward the bottom of the page.
   a. Sketch the situation.

   b. What is the direction of the magnetic field?

   c. What is the magnitude of the magnetic field?

   d. Would the magnitude of the force increase, decrease of stay the same if the wire is placed at an angle of 45°? Explain.

   e. Sketch two ways to orient the wire so that it experiences zero force.

4. A 0.20 m long wire carrying 3 A current to the left is placed in a 2.5 T magnetic field that points to the left. What is the force on the wire?

Force on a Current Carrying Wire

5. A 10 cm long wire experiences 4 N of force to the right when placed in a 3.5 T magnetic field directed toward the bottom of the page.
   a. What is the magnitude and direction of the current?

   b. If the current is doubled, what is the force on the wire?

6. A wire carrying 0.55 A current into the page is placed in a 2 T field that points to the right. A force of 0.45 N is exerted on the wire.
   a. What is the direction of the force?

   b. What is the length of wire in the field?

   c. If the wire has 2.5 Ω of resistance, what is the voltage of the wire?

Answers:

1) 7.84 N 2) 3 N, out of the page 3. b) into the page c) 2.35 Td) decrease
e) into or out of the page (so that it is parallel to the wire) 4) 0 N
5. a) 11.4 A, out of the page b) 8 N, same direction
6. a) bottom of the page b) 0.41 m c) 1.38 V

Lab 36-2: Magnetic Induction

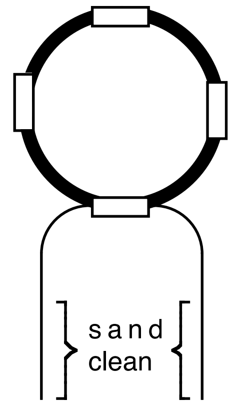
Purpose:
1. To explore the magnetic field created by a coil of wire.
2. To explore how a coil of wire interacts with magnetic fields.
3. To make a simple speaker and explain how a speaker works.

Materials:

2 coils		2 mini-stereo to alligator leads
1 ring magnets		2 wires & alligator clips
1 mini-amp	1 iPod	1 mini-stereo to mini-stereo cable

Procedure:

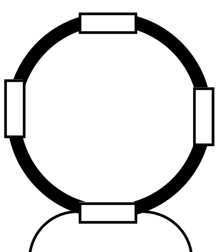
Part 1: Make 2 Coils



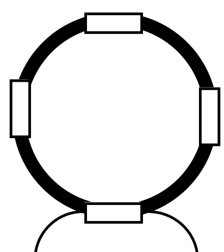
1. Tightly wrap a strip of wire around the piece of PVC tube. Leave the ends of the wire free.
2. Carefully remove the coiled wire from the PVC, and then use 4 little pieces of tape to tightly tape up 4 sides of the coil.
3. Using sandpaper, clean off the ends of the wires so that there is a about 1/2 inch of clean bare wire. The coil should look like the picture to the right.
4. Repeat the above steps to make a second identical coil.

Part 2: The Magnetic Field created by a coil (DC)

1. Attach one of the coils to the power supply with 2 wires and alligator clips.
2. BRIEFLY turn up the power. Does the coil do anything? (It will get hot – so briefly means less than a second.)
3. Put the magnet under the coil. BRIEFLY turn up the power. What happens?
4. Flip the magnet over, and put it back under the coil. (Remember that one side of the magnet is a north pole and the other side is a south pole.) BRIEFLY turn up the power. What happens?
5. Explain what was happening:
6. Draw the resulting magnetic field in the middle of each coil for the two situations shown:



Clockwise current



Counter-Clockwise current

Part 3: The Magnetic Field created by a coil (AC)

1. Attach one of the coils to the AC side of the power supply with 2 wires and alligator clips. (The AC side is the yellow plugs.)
2. BRIEFLY turn up the power. Does the coil do anything? (It will get hot – so briefly means less than a second.)
3. Put the magnet under the coil. BRIEFLY turn up the power. What happens?

Lab 36-2: **Magnetic Induction**

4. Flip the magnet over, and put it back under the coil. (Remember that one side of the magnet is a north pole and the other side is a south pole.) BRIEFLY turn up the power. What happens?

5. How does the amplitude and the frequency of the vibrations depend on the voltage?

6. Explain what was happening:

Part 4: Magnetic Induction in the second coil

1. Connect the second coil to the mini-amp using the stereo-to-alligator cable. Turn on the mini-amp and turn it all the way up.
2. Lightly tap the coil on the table. What happens?
3. Lightly tap the coil on the magnet. What happens?
4. Place the coil on the magnet. What happens?
5. Move the coil back and forth across the magnet. What happens?
6. What must be happening for there to be a "click" or a noise coming from the mini-amp?

7. With the original coil still plugged into the AC, turn on the power VERY LOW. (Just rotate the power knob a little bit – you probably won't even notice a current reading.) Now place the second coil on top of the first. What happens?

8. What happens to the sound as you increase or decrease the power? What happens to the sound as you move the coils around?

9. Repeat the above, but with the first coil plugged into the DC side of the power supply. Explain what happens and why it is different from the AC side.

10. Disconnect the coil that is connected to the power supply and instead connect it to an iPod using the other stereo-to-alligator cable. (Now one coil should be connected to the mini-amp and the other to the iPod.) Play a song on the iPod and move the coils close together. What happens?

Part 5: Speakers

1. Disconnect both coils. Connect the iPod to the mini-amp using the stereo-to-stereo cable. Then connect one of the coils to the "EXT SPKR" of the mini-amp.
2. Turn on the iPod and the mini-amp. (Both at least 1/2 power.)
3. Take the coil and press it to your head next your ear using the magnet. What happens?
4. Press the coil onto the end of a cup with the magnet. Try a few different cups. What happens?
5. Explain.