Magnetic Fields
Spring 2020

Introduction

The purpose of this experiment is to observe the magnetic fields, $\vec{B}$ of a bar magnet, a *coil* of current-carrying wire, and a *straight* current-carrying wire. *Note that there are three templates at the end of these directions that you will be completing and turning in with your lab report.*

Experiment

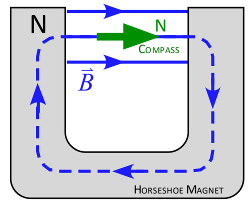


Figure 1. *B* in horseshoe magnet

1. THE $\vec{B}$ FIELD OF A PERMANENT BAR MAGNET
   a. Find the orientation of your compass with the large horseshoe magnet (**Figure 1**), *taking care* not to get the compass too close to the magnet.
   b. Note that the red bar magnets have either a 'bump' or a white dot on one end. Use your compass to determine if this is the north or south pole of the magnet. Draw a sketch of the magnet and your compass, and then explain how you determined the magnet polarity. *Note that the magnets in the lab may not be oriented the same!*
   c. Your instructor will show you how to use a *teslameter* to measure the $\vec{B}$ field *at each end* of your bar magnet (units = *Tesla*). Also measure $\vec{B}$ for both poles of the large horseshoe magnet.
   d. Locate the lab bench with a sheet of paper containing an arrangement of compasses (**Figure 2**). Place your magnet in the center of the page, being careful not to disturb the compasses. Using *Template 1: B Field of a Bar Magnet*, draw arrows to show the direction each compass points. Remember that each compass needle represents the direction of $\vec{B}$ at that location.

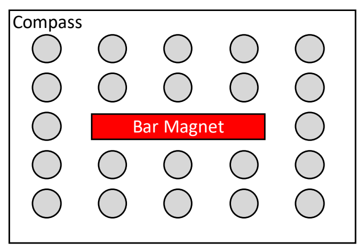


Figure 2. Bar magnet & compasses

   e. Label the north and south poles of your magnet on the template, along with the side that contains the bump or white dot.
   f. Rotate your magnet 180° on the page, and note the effect on the compass needle directions.

2. THE $\vec{B}$ FIELD OF CURRENT CARRYING COILS
   a. Appearance of $\vec{B}$ around a small coil: Locate the lab bench with a small vertical coil mounted on a board, surrounded by compasses (**Figure 3**). Note the direction that each compass points when no current flowing (*the switch is vertical, creating an open circuit*).

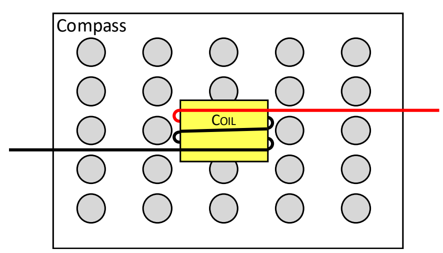


Figure 3. Wire coil & compasses

   b. The apparatus contains a switch with two positions, labeled '"Direct" and "Reverse", that controls the direction of the current. Move the switch to the side labeled "Direct", and a small amount of direct current will flow <u>into the coil through the red wire</u>.
   c. Using *Template 2: B Field of a Current Carrying Coil*, draw arrows to show the direction each compass points (note that there is also a compass inside the coil, represented with dashed lines). Also draw a few arrows on the coil wire to represent the direction of current.

      <u>*Don't leave the switch closed too long; the coil will get very warm*</u>*!* Move the switch to its vertical position when you're finished.
   d. What do you think will happen to the compass direction when the current direction through the coil is reversed? Write down your prediction, then move the switch to "Reverse" and note the result.

e. Solenoid measurement: A solenoid is a coil whose length is greater than its diameter. Locate the solenoid, and use the *teslameter* to measure the maximum strength of the $\vec{B}$ field at the point shown (**Figure 4**).

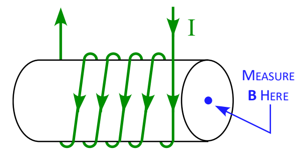


Figure 4. Direction of I through solenoid

f. Draw a *large* sketch of the solenoid, including the direction of current in the coil and the direction of the $\vec{B}$ field (note the direction the wire wraps around the core).

g. Solenoid calculation: Record the current through the solenoid, I, and measure the length of the solenoid, ℓ (just measure the length of the coiled wire; don't include the plastic end supports).

h. Calculate the magnitude of $\vec{B}$ at the *end* of a solenoid using the following:

$$B = \frac{\mu_0 NI}{2\ell}$$

where μ_o is a constant $\left(12.57\times10^{-7}\ \frac{N}{A^2}\right)$, and N is the number of turns in the solenoid (N = 560 for this solenoid). Keeping I in *Amperes*, and ℓ in *meters* will allow you to calculate B in units of *Tesla*.

i. Calculate the % difference between your calculated B and your measured value from step *2e*.

3. THE $\vec{B}$ FIELD OF A CURRENT CARRYING STRAIGHT WIRE.

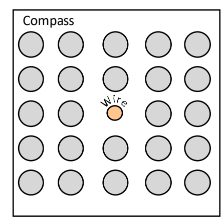


Figure 5. B around straight wire

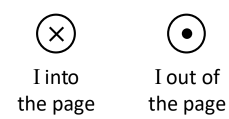


Figure 6. Showing direction of I

a. Several compasses are arranged on the platform of the apparatus around the vertical wire (**Figure 5**). Observe their direction when no current flows through the wire.

b. Use the right hand rule to predict the direction of the $\vec{B}$ field when current travels *down* into the platform.

c. The apparatus contains a switch with two taps ("Direct" and "Reverse") which control the direction of current. The "Direct" switch will send current *down* into the platform. Press and hold the "Direct" switch, recording the compass needle directions on *Template 3: B Field of a Current Carrying Straight Wire*. Use the appropriate symbol from **Figure 6** to show the current direction. Was your prediction correct?

d. Again predict the direction of the compass needles when the "Reverse" switch is pressed. Try it, and compare the results with your prediction.

4. HOW MUCH CURRENT DOES IT TAKE TO MAKE AN ELECTROMAGNET AS STRONG AS A PERMANENT MAGNET?

In step *2h*, you calculated the magnitude of B at one end of the large solenoid. How much current would you have to pass through this solenoid to give it the same B as the bar magnet, or the horseshoe magnet?

a. *Algebraically* solve the equation in step *2h* for the current, I.

b. Calculate the amount of current you would have to pass through the solenoid in order to produce the *same* B as the strongest pole measured on your bar magnet in step *1c*.

c. Repeat this calculation, this time determining how much current would have to pass through the solenoid to give it the same B as the strongest pole of the horseshoe magnet you measured.

5. FUN WITH MAGNETISM!

There are a few other pieces of equipment in the lab for you to experiment with:

a. Visualizing $\vec{B}$: Locate the clear plastic box near the horseshoe magnet; it contains iron filings suspended in silicon oil. Hold this container in various positions near the horseshoe magnet, noting the path of the field lines.

b. The force on a current-carrying wire in an external $\vec{B}$ field ("The Jumping Wire"): ***YOUR INSTRUCTOR WILL HELP YOU WITH THIS ONE!***

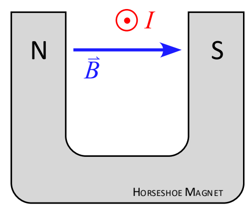


Figure 7. Current carrying wire in external *B* field

i. Place a wire between the poles of the horseshoe magnet. Use the right-hand rule to predict the direction the wire will "jump" when current travels in the direction shown in Figure 7 (*out of the page*).

ii. *Briefly* press the tap switch, and see if your prediction was correct!

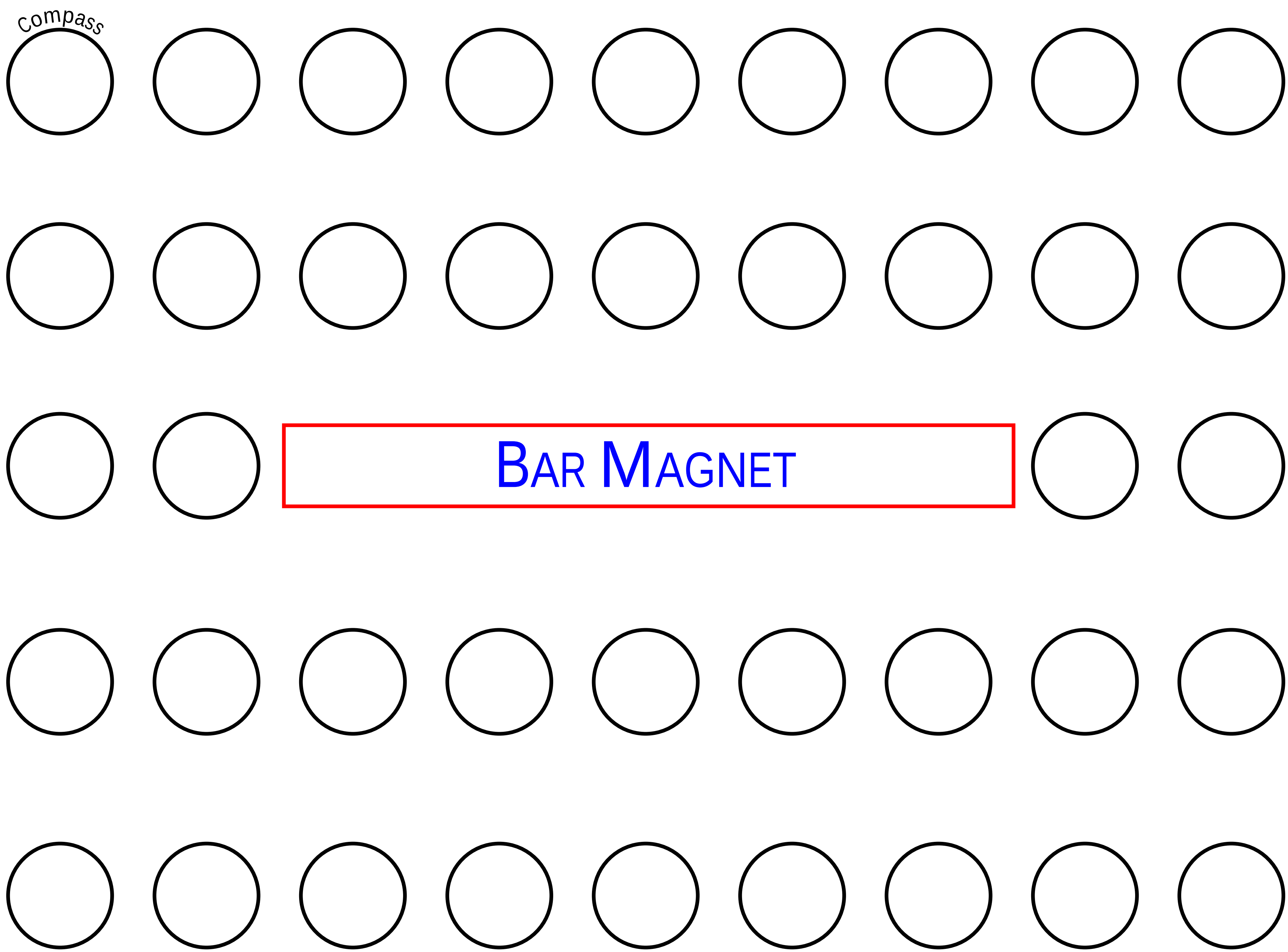
iii. Draw a sketch showing the correct orientation of the magnet, the $\vec{B}$ field, the current *and* the force exerted on the wire.

c. The interaction of charged particles and a $\vec{B}$ field: An old computer has been placed in the lab. Take your bar magnet, move it around in front of the monitor, and observe the effect. ***Don't try this with the other lab computers, or your own computer!***

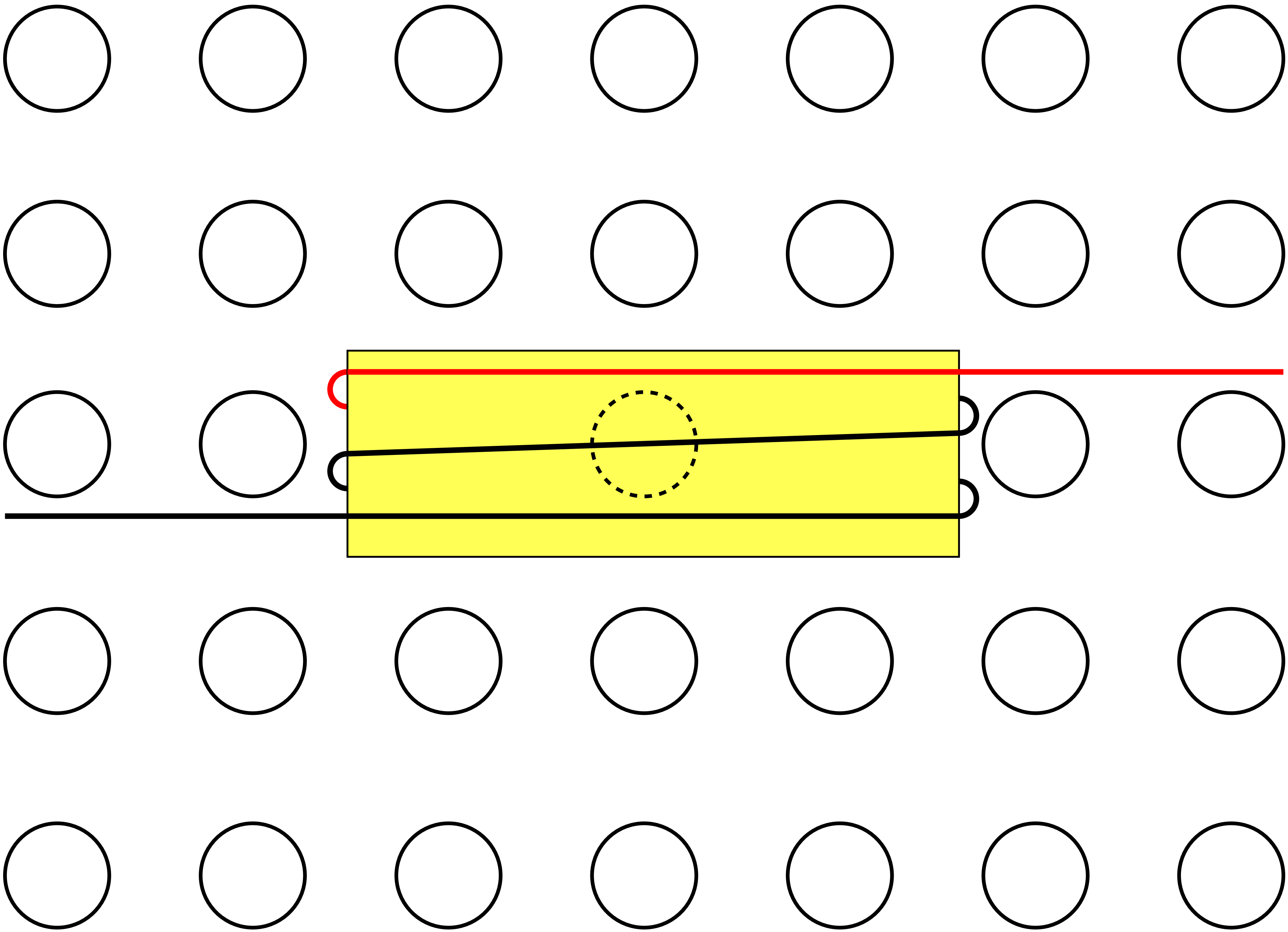
Discussion

- Summarize what you have learned about the direction of magnetic fields in permanent magnets, wires and coils.
- Discuss the similarities between the magnetic field observed around the small coil (step *2c*) and the field around the bar magnet (step *1d*).
- In step 4, you calculated the amount of current that needs to be passed through the solenoid to produce the equivalent magnetic field strength as the permanent magnets. Is this a large amount of current?
    - As a comparison, a current of 0.2 A through the heart can be fatal, and a typical room air conditioner can use around 8 A – a considerable amount. How do the currents you calculated compare with that used by a typical air conditioner?

Template 1: $\vec{B}$ Field of a Bar Magnet



Template 2: $\vec{B}$ Field of a Current Carrying Coil



Template 3: $\vec{B}$ Field of a Current Straight Wire