Magnetic Fields

TA's signature allowing you to take the quiz or leave ____________

Your Name ____________________________

Partners' Names ____________________________

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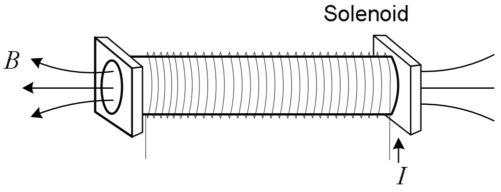
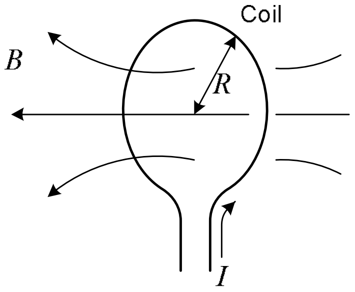
Obtained reasonable experimental results? yes ☐
Answered questions? yes ☐
Cleaned your table? yes ☐

Magnets are very fragile. Exercise caution while dealing with the bar magnet.

Introduction

As you learned in the lab of electric fields, the field mediates its force. The magnetic field does the same. The similarity between electric and magnetic phenomena is referred to as two agents that attract and repel each other. For instance, electric fields are created with positive and negative charges, and magnetic fields are created with N- and S-poles. However, unlike electric charges, magnetic poles, N and S, are always pair. A bar magnet can be a good example to depict this particular property. Even though you slice the magnet in pieces, any of the pieces has both poles. The SI unit of magnetic field is tesla (T). Another unit is called gauss, which is converted into tesla multiplied by 10^{-4}. On the other hand, the magnetic field has a peculiar property; namely, the field can also be associated with electric currents. When you produce a current, it creates a magnetic field according to the geometrical shape of the conducting wire as shown. For example, if you apply a current to a solenoid, which is a cylindrical coil, the magnetic field will be:





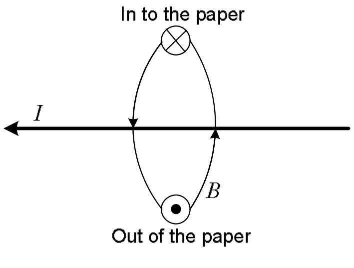
$$B = \mu_0 n I$$

where μ_0 is the permeability in free space, $4\pi \times 10^{-7}$ Tm/A, *n* is the turns per unit length, and *I* is the current you apply to the solenoid. When it is a circular coil, the magnetic field at the center of the circle will be:

$$B = N\frac{\mu_0 I}{2R}$$

where *N* is the total number of the turns, R is the radius of the loop, and the others are the same as above.

Another important fact is that the direction of magnetic fields depends on the direction of the current as shown in the figure. This is also illustrated by the Right Hand Rule (RHL), or the right-hand-thumb rule.



Objectives:

- To see the distance-dependent property of the magnetic fields due to a bar magnet
- To test the properties of magnetic fields due to current (direction and magnitude)
- To find the difference between a solenoid and a coil

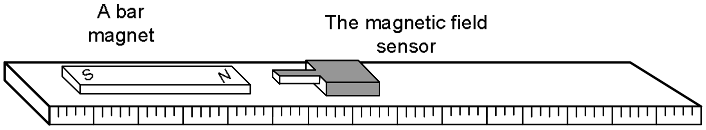
1. Distance dependence of the field strength :

- **For the magnetic field sensor, put the bar magnet far from the sensor, then press the tare (zero) button to reset the sensor.**

- **In the magnetic field sensor, switch the “axial”, not “radial.”**

- **The range select of the sensor should be “1 ×.”**

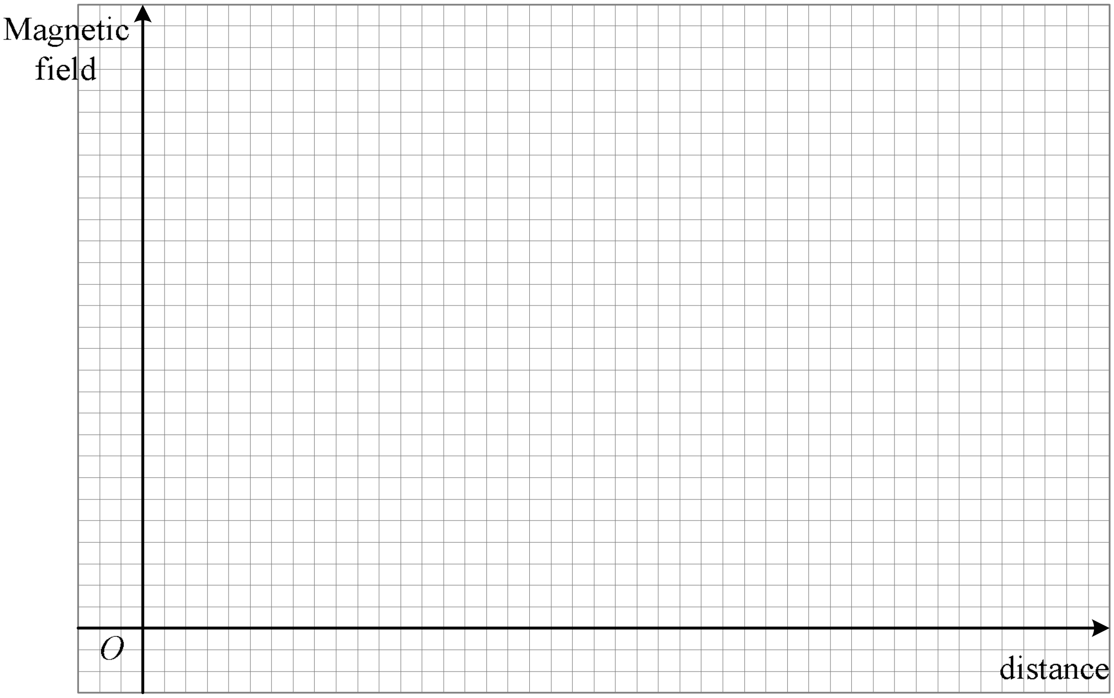
- **Set up the experiment with a precision track, a bar magnet, and the magnetic field sensor as follows: The distance between the magnet and the sensor should starts at about 2 cm (0.02 m).**



- **Record the magnetic field for each distance. The increment should be about 1 cm. Try to take 8 values for plotting.**

Distance from the magnet (cm)	The magnetic field detected by the sensor (gauss)

Plot the above data in the following graph.



Question:
How does the magnetic field depend on the distance? Is it similar to the other fields, such as electric field?

2. Magnetic fields created by currents

2-1 Magnetic fields with a solenoid

The magnetic field produced by a solenoid with current is given as:

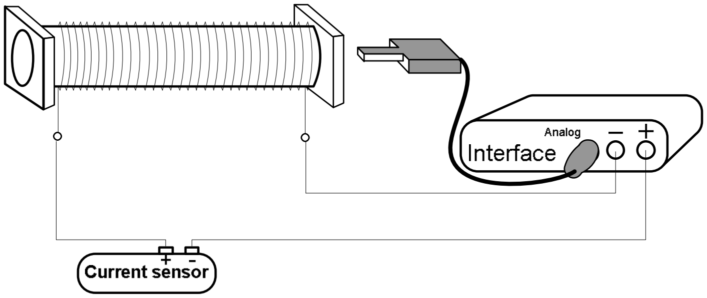
$$B = \mu_0 n I$$

μ_0 is the permeability in free space, $4\pi \times 10^{-7}$ Tm/A. I is the current. n is the number of turns per unit length calculated by the total number of turns, N, divided by the length of the solenoid, ℓ.

- **Measure the length of the solenoid and calculate the number of turns per unit length.**
- **Set up the experiment as follows, and measure the magnetic field for each current.**
- **Start up DataStudio to use the DC power supply.**
- **Click “Digit” in the display component of DataStudio.**
- **In the magnetic field sensor, switch to “Axial.”**

Click any channel to add a sensor.

Click here to have DC voltage.



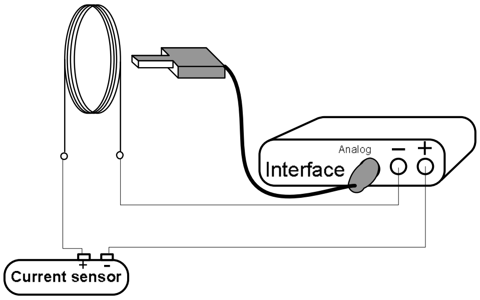
The total number of turns __1340__, The length ℓ ______________(m),

Turns per unit length, n =________________ (turns/m)

DC voltage from the interface	Current (A)	Magnetic field measured (gauss)	Magnetic field converted into tesla, B_{ex} (gauss × 10^{-4})	Magnetic field calculated (T) B_{cal}	% difference $\frac{\lvert B_{ex}-B_{cal}\rvert}{(B_{ex}+B_{cal})/2}\times 100$ (%)
5 V					
4 V					
3 V					
2 V					

Question: How well do the experimental results agree with the expected values?

2-2 Magnetic fields with a coil



The magnetic field produced by a coil with current is given as:

$$B = N\frac{\mu_0 I}{2R}$$

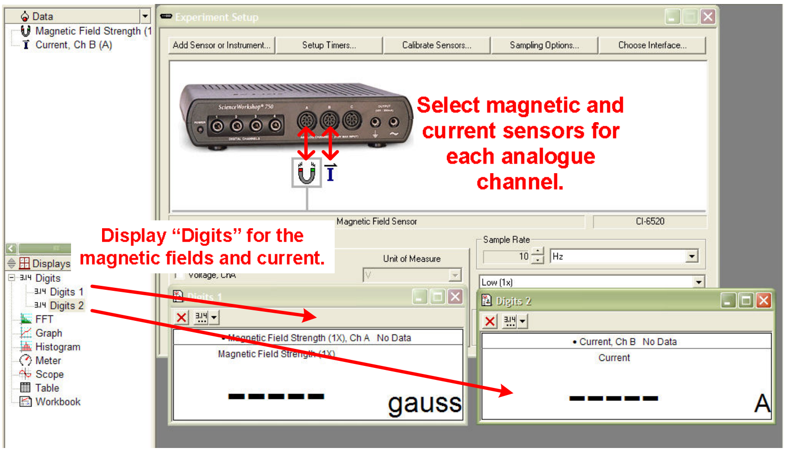
μ_0 is the permeability in free space, $4\pi\times10^{-7}$ Tm/A. I is the current. N is the number of the total number of turns. R is the radius of the coil.

- **Hypothesize the experiment. Write a proper procedure to obtain the magnetic field from the coil, knowing that the number of turns of the coil is 20.** (Refer to the above theory and picture.)

- **The conceptual activity**

Directions of the magnetic field and current

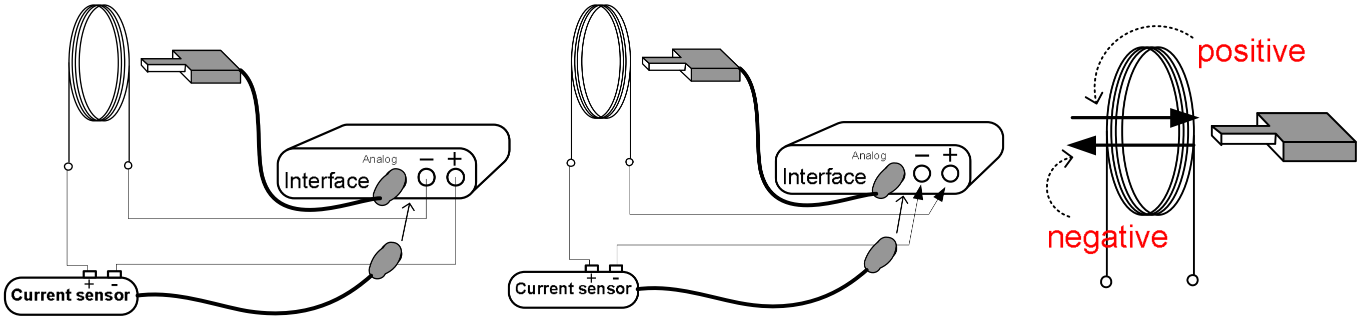
Procedure for DataStudio:



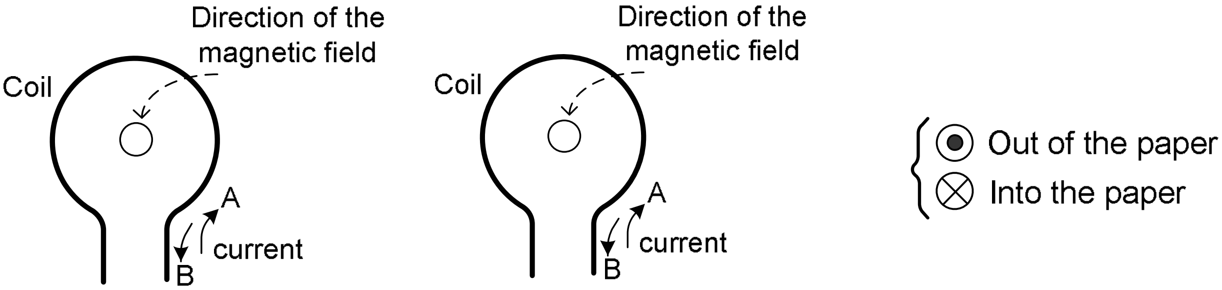
Select magnetic and current sensors for each analogue channel.

Display “Digits” for the magnetic fields and current.

Set up the experiment as follows. Try two different orientations of the current flow: [Note that the positive magnetic field indicates that the field comes into the sensor; and the negative has to be the opposite. The current is from the positive to negative voltages.]

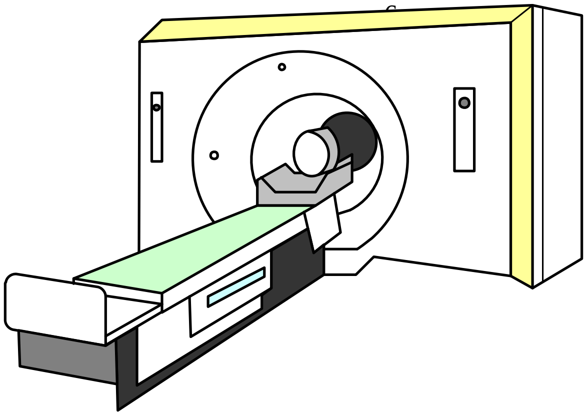


Question: From the above experiment, record the directions of the magnetic fields and currents below. Put the symbol “Out of the paper” or “Into the paper” as shown according to the read from the magnetic field sensor. Select **A** or **B** for the direction of current in terms of the connections to the power supply as shown above. <u>Are they consistent with the right-hand law?</u>



Question: How do you explain the differences between a coil and a solenoid from this experience?

Questions you may want to explore



One of the applications of solenoids is the MRI (Magnetic Resonance Imaging). Let’s imagine that a patient lies down in the center of a solenoid. This is exactly what an MRI is though it is simplistic for the reality. In general, an MRI can create 0.2 – 1.5 T of the magnetic field. If it uses a stronger magnetic field, the image can have a higher resolution. Now, think about the following:

- How about if you compare the magnetic field you measured in this lab with the field that a typical MRI generates? How would you imagine the amount of the current flow and size of the coil that an MRI may use? [Look up actual specifications of an MRI, too.]

- How strong is the 1.5-T magnetic field compared with other daily-life (this lab) magnetic fields? How much weight could it lift? If such magnetic field is used toward magnetized materials such as credit cards or a wrist watch, what will happen?

- How would you understand that the medical staff is very vigilant to remove all of the metal items from the MRI room? [Imagine what would happen with metal items after turning on the MRI.]