NAME PERIOD DATE

MAGNETIC FIELD STRENGTH

How is the strength of the magnetic field at the center of a current-carrying coil dependent on the coil current?

Objectives

- Experimentally determine a mathematical relationship between the current and the magnetic field at the center of the current-carrying coil.

Materials and Equipment

- Data collection system
- PASCO Wireless 3-Axis Magnetic Field Sensor
- Sensor rod
- PASCO AC/DC Electronics Laboratory
- Magnet wire or enameled wire, fine gauge (~10 m)
- Power supply, 18-VDC, 3-A
- 4-mm banana plug patch cord (2)
- Wire lead
- Support rod, 45-cm
- Table clamp
- Right angle clamp
- Sandpaper
- Scissors or wire cutters
- Ruler

Safety

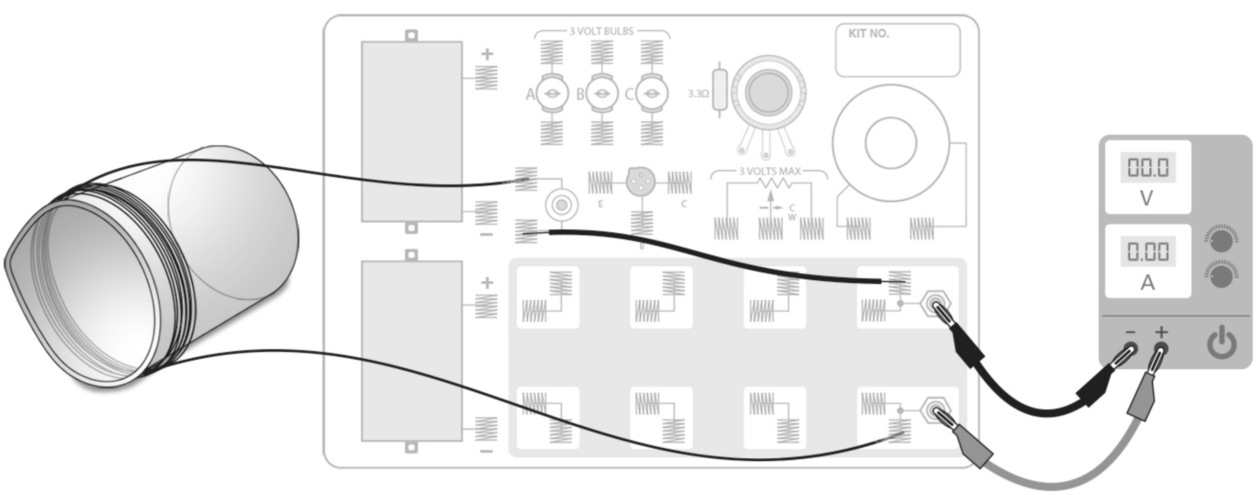
Follow these important safety precautions in addition to your regular classroom procedures:

- Do not allow current to flow through the wires any longer than a few seconds. The wires (and possibly the power supply) can become hot and cause burns and damage equipment. Including the push-button switch in the circuit helps prevent this problem.

Procedure

1. Wrap 10 loops of wire around the top of a 100-ml (or smaller) beaker, forming a coil. Leave about 20 cm of straight wire on each end and use sandpaper to sand off about 1 cm of insulation from the tips of each end of the wire.

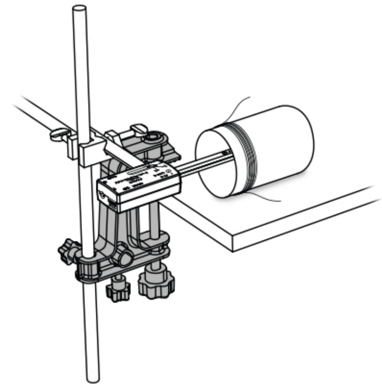
2. Connect the power supply, coil, and switch on the AC/DC Electronics Board as shown. Make sure you include the push-button switch in your circuit.



3. Turn the power supply on, press and hold the switch on the circuit board, and adjust the power supply so that 0.50 A of current is flowing through to the coil. Release the switch every few seconds and after the adjustment is complete.

   NOTE: Do not hold the switch for more than a few seconds. Repeatedly press the switch to adjust the power supply if needed, waiting for 1–2 seconds between adjustments.

4. Mount the magnetic field sensor using the support rod, the sensor rod, and clamps so the tip of the probe is held at the center of the coil, as shown. A couple of erasers placed on either side can help keep the beaker from rolling.



5. Connect the magnetic field sensor to the data collection system, and then create a digits display of Magnetic Field Strength (Axial) with units of mT.

COLLECT DATA

6. Zero the magnetic field sensor in your data collection system, and then begin recording data.

7. Press the push-button switch to close the circuit, quickly note the magnetic field value, and release the push-button switch.

8. Stop data collection and record the magnetic field value into Table 1.

9. Repeat the data collection steps for current values of 1.0, 1.5, 2.0, 2.5, and 3.0 A. Record each corresponding magnetic field value into Table 1.

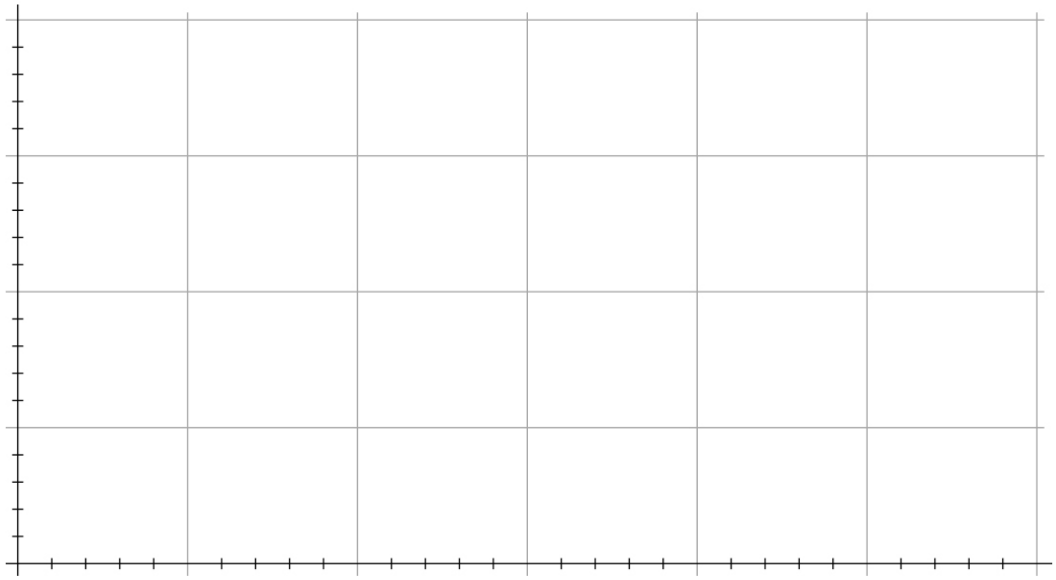
Data Collection

Table 1: Magnetic field and current for a current-carrying coil with constant radius

Current (A)	Magnetic Field (mT)
0.50	
1.0	
1.5	
2.0	
2.5	
3.0	

1. Plot a graph of *magnetic field* on the y-axis and *current* on the x-axis on the blank Graph 1 below. Be sure to label both axes with the correct scale and units.

Graph 1: Magnetic field versus current of a current-carrying coil with constant radius



2. Draw a line of best fit through your data in Graph 1. Determine and record the equation of the line here:

   Best fit line equation: ____

Questions and Analysis

1. Based on your data, how is the magnetic field mathematically related to the current in a current-carrying coil? Use terms such as proportional, inversely proportional, linear, or quadratic in your response.

2. The magnetic field B created by a long, straight, current-carrying wire is given by the equation

$$B = \frac{\mu_0}{2\pi}\frac{I}{r}$$

   where I is the current, r is the distance from the wire to the point where the magnetic field is measured, and μ_0 is the vacuum permeability constant. How is your data related to this equation?

3. The magnetic field at the center of a current-carrying coil is given by the equation

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

where N is the number of loops and r is the radius of the coil. How is your data related to this equation?

4. Using the slope from your graph, the number of loops in your coil and the radius of your coil, determine an experimental value for the vacuum permeability constant μ_0.

5. Compare your experimental value and the actual value of the vacuum permeability constant μ_0:1.3 × 10^{-7} T·m/A.

6. What are factors that might have caused error in your experimental value for the vacuum permeability constant?