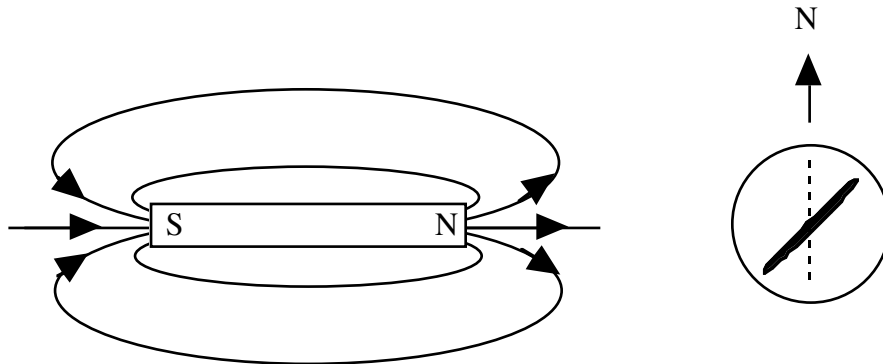


MAGNETIC FIELD MAPPING

- Objectives:**
- To learn how to find magnetic field
 - To gain fluency in sketching magnetic field lines.

- To Do Before Lab:**
- Read this lab
 - Solve the following problem:

A compass sitting on a tabletop is pointing north because of the earth's magnetic field. A bar magnet is brought near the compass, the compass needle deflects to the east as shown below, and remains at rest. Assume that the magnetic field due to the bar magnet points east at the position of the compass. The magnetic field at the compass is due to the vector sum of the magnetic field of the earth and the magnetic field of the bar magnet. If the angle of deflection of the compass is 76° , how does the magnitude of the field due to the compass compare to the magnitude of the earth's magnetic field?



What is the general relation between the field strength of the magnet, the deflection angle, and the earth's magnetic field?

Aparatus: DC power supply, Keithley multimeter, Silva magnetic compass, 1800-turn solenoid wound on PVC tubing, connecting leads, wood, aluminum and iron cores, wooden platform and rail, magnifying glass.

Introduction

It was known more than 2000 years ago that certain naturally occurring stones (containing the mineral magnetite) attract small pieces of iron. About 1000 years ago navigators had begun to use the magnetic compass as a guidance tool. However, the connection between electricity and magnetism was not discovered until about 1820, when Hans Oersted first noticed that a compass needle was affected by an electric current.

In each of the cases above, one object exerts a force on another object without any obvious physical contact. To explain this magnetic 'action at a distance' physicists use the concept of a *magnetic field*. In this lab you will examine properties of the magnetic field around a *solenoid*, a long wire wrapped many times around a cylindrical core.

Just like the electric field, the magnetic field is a vector; it has a magnitude and a direction. The *direction* of the magnetic field at a point is conveniently determined by placing a compass at the point. The compass needle points in the direction of the magnetic field. The *magnitude* of the magnetic field can be defined in terms of the torque the field exerts on a "test compass", although this definition is not of much

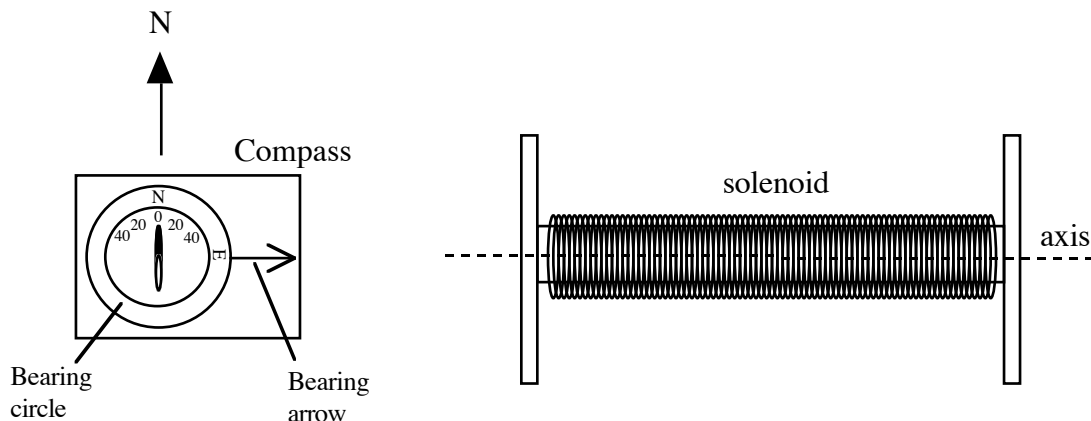
practical use. In this lab we will determine the magnitude of the magnetic field of a solenoid relative to the magnetic field of the earth.

Part I:

Build a series circuit containing the Filtered D.C. Power Supply, the solenoid, and the Keithley multimeter. Set the multimeter to measure DC current with a range of 0-2000 mA. Turn on the power supply and adjust the control knob until the voltage shown on the power supply meter is 20 V. Record the current reading on the Keithley multimeter and then turn the power supply back down to zero. Determine the resistance of the solenoid and the heat dissipated per second by the solenoid (power). Include units.

Caution: Notice that the power in this circuit is quite large. With a current of $>1\text{A}$ the solenoid may eventually get so hot that it will melt the PVC tube or the enamel insulation on the copper wire. For comparison, think about how hot a typical 60 W light bulb gets. **Never run the solenoid for a long period of time with a current that is this large, and throughout each experiment check the solenoid frequently to make sure it is not too hot.**

1. Investigating the direction of the magnetic field produced by a solenoid
 - a) Set the current through the solenoid at about 1 A. Move the compass around on the platform and observe how the direction of the magnetic field varies with position. Note especially the direction of the magnetic field along the axis of the solenoid.
 - b) Reverse the direction of the current through the solenoid. How does this affect the direction of the magnetic field?
2. The effect of current on the strength of the magnetic field
 - a) Place the large compass in the wooden rail, 20 cm from the center of the solenoid. With **no current** in the circuit, carefully adjust the setup so that the axis of the solenoid is perpendicular to the horizontal component of earth's magnetic field as shown in the diagram below. To check this alignment, turn the bearing circle of the compass until E is lined up with the bearing arrow and then rotate the entire apparatus until the compass needle is pointing at 0° on the small black scale that runs inside the bearing circle. Use the magnifying glass to help you see the needle position.



- b) Devise an experiment to determine the relationship between the solenoid's \mathbf{B} -field and the current through the coil. Write the procedure in your notebook. Be sure to record uncertainties. Between measurements turn off the power supply and check that the apparatus is aligned properly and that the solenoid is not too hot. Here are some

questions to help you on your way: What is the ratio of the solenoid's \mathbf{B} -field relative to the earth's \mathbf{B} -field? And what is the relation between the deflection of the compass needle and the solenoid's \mathbf{B} -field? Find the mathematical relationship between magnetic field strength and current? Celebrate your result with a box.

3. Variation of field strength with distance from the solenoid: Devise an experiment to determine the variation of the \mathbf{B} -field with distance from the solenoid. Keep the current set at a constant setting no greater than 1.0 A. As before write up your procedure carefully.

4. We derived the magnetic field of a solenoid in class. Compare the theoretical result with your data. One nice way to do this is to create a new calculated column using the functional form of the magnetic field strength as a function of distance along the axis. You will have to choose a point to normalize the field. In your summary comment on the quality of the match between the theoretical result and the data.

5. Magnetic field summary: Make a *careful* sketch of the magnetic field lines in the region around the solenoid and write a brief description. Be sure to indicate where you have quantitative information about the field and where you only have qualitative information. Feel free to use the compass to help with the sketch.