Courtesy of Prentice Hall Press
Cunningham, J. and N. Herr
Hands-On Physics Activities with Real-Life Applications
West Nyack, New York, 1994
Simon & Schuster

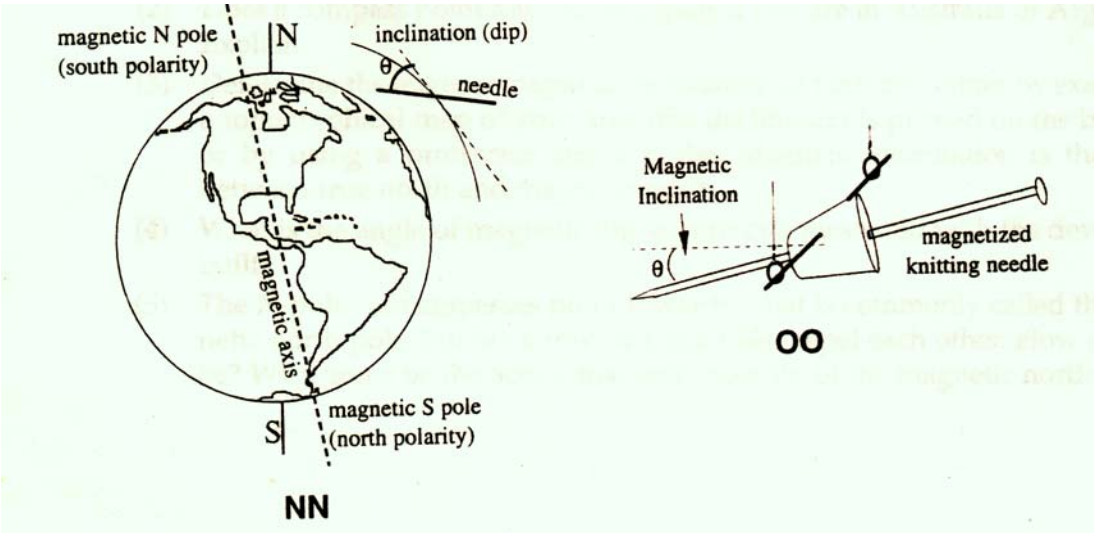
Geomagnetism

Concepts to Investigate: Earth's magnetic field, magnetic declination, .magnetic dip (magnetic inclination), magnetic north and south poles.

Materials: Compass, knitting needle, washers, thread, sewing needle, cork.

Principles and Procedures: Although the Earth behaves as a giant magnet, the magnetic N- and S-poles are rather mobile and do not coincide with geographic north and south poles. By comparing maps made during the past 100 years, you will notice that the location of the magnetic N- and S-poles tend to wander. At times the magnetic north pole has been located on Bathurst Island, and at other times it has been located in the waters between the islands in Canada's Northwest Territories. Figure NN shows that the magnetic axis of the Earth is slightly different from the axis of rotation.

When using a compass to orient a map, it is important to realize that the magnetic north pole is actually 1,800 kilometers from the geographic North Pole, in the direction of Chicago, Illinois. If you lived in Chicago, you will not need to correct for this difference because magnetic north and true north are shown on the same longitudinal line that goes through Chicago. If, however, you live in Vancouver, British Columbia, magnetic north is 24 degrees to the east of true north, and so you must compensate by shifting the angle of your map 24 degrees to the west to align with true north. Compensating for the angle of magnetic declination is extremely important for sailors, backpackers, aviators, and others who navigate using a map and compass. Use a globe to estimate the angle of magnetic declination for your city and compare this value with the value printed on a topographic map of your region.



The strength of the Earth's magnetic field varies like that of a bar magnet, strongest at the poles and weakest at the equator. In addition, the angles of magnetic flux lines vary across the surface of the Earth, vertical at the magnetic poles and tangential to the Earth's surface at the magnetic equator. Consequently, the angle of the magnetic flux lines are correlated with strength of the magnetic field. The steeper the angle of magnetic dip, the greater the magnetic strength. If the field lines in your area are inclined at 90^{o},then you must be standing immediately over a pole where the field strength is greatest. If the field lines are parallel to the surface of the Earth, the inclination is zero and you must be near the equator, where magnetic fields are weakest. It is possible to measure the angle of magnetic dip and make inferences about field strengths using the magnetic dip (inclination) needle shown in Figure OO.

To make a magnetic dip needle, push an unmagnetized knitting needle through a cork and a sewing needle at right angles to it, as illustrated. Besides the apparatus between the rims of two glasses or from suspended washers, as shown. The apparatus should be arranged so the tip of the knitting needle points toward the magnetic north pole. Carefully push the knitting needle back and forth through the cork until it is balanced in a horizontal position. Use a carpenter's level to determine if it is horizontal. Now magnetize the knitting needle by stroking it with a permanent magnet. Starting from the cork, stroke toward the tip using the S end of the magnet. After stroking this half 30 times, stroke the other half an equal number of times with the N-pole of the magnet, moving from the cork to the head of the needle. By stroking the needle in this fashion, the tip acquires a N polarity while the head acquires a S polarity. Place the apparatus back on its supports and allow it to stabilize. Use a protractor to measure the angle of dip (the difference between the current angle and the horizontal position, Figure OO).

Questions

(1) The magnetic north pole is currently located on Bathurst Island in Northern Canada. Use a globe to determine where the magnetic South pole is located.

(2) Does a compass point toward the S-pole if you are in Australia or Argentina? Explain.

(3) Determine the angle of magnetic declination of your city either by examining a topographical map of your area (the declination is printed on the bottom), or by using a protractor and a globe. Magnetic declination is the angle between true north and magnetic north.

(4) What is the angle of magnetic dip at your city measured with the device you built?

(5) The N-poles of compasses point towards what is commonly called the magnetic north pole, but we know that like poles repel each other. How can this be? What must be the actual magnetic polarity of the magnetic north pole?

FOR THE TEACHER

Geomagnetism

Discussion: Hikers and backpackers use topographic maps when venturing into the wilderness. These maps indicate detailed topographic features and indicate the angle of magnetic declination so they may be correctly aligned with a magnetic compass. Show students how to orient such maps. Topographic maps may be obtained from sporting goods stores or directly from the United States Geological Survey (USGS).

Answers: (1) The magnetic south pole is located just off the coast of Antarctica, due south of Adelaide, Australia.

(2) The field lines of the Earth are continuous from pole to pole just as are the field lines of a bar magnet. Thus, a compass continues to point to the magnetic north pole regardless of its position on the Earth's surface.

(3) Angles of declination for major North American cities are: Halifax, 24^{o}W; Boston, 15^{o}W; New York, 10^{o}W; Richmond, Virginia, 5^{o}W; Chicago, 0^{o}W (on the agonic line; the line of zero declination); St. Louis, 5^{o}E; Austin, 10^{o}E; San Diego, 15^{o}E; Los Angeles, 18^{o}E; Portland, 20^{o}E ; and Vancouver, 25^{o}E. Honolulu, Hawai‘i has a declination of 11^{o}E.

(4) The angle of magnetic dip (or inclination) is 25-30^{o} for most of the United States, Canada, Japan, and Europe. It is 0^{o} along the magnetic equator in portions of Peru, Nigeria, Sri Lanka, and Thailand.

(5) Magnetically, the magnetic north pole of the Earth is a S-pole. This is confusing for most students. Some of this confusion can be avoided if we consider the N-poles of compasses and magnets to be "north-seeking" poles rather that "north" poles.