National Aeronautics and
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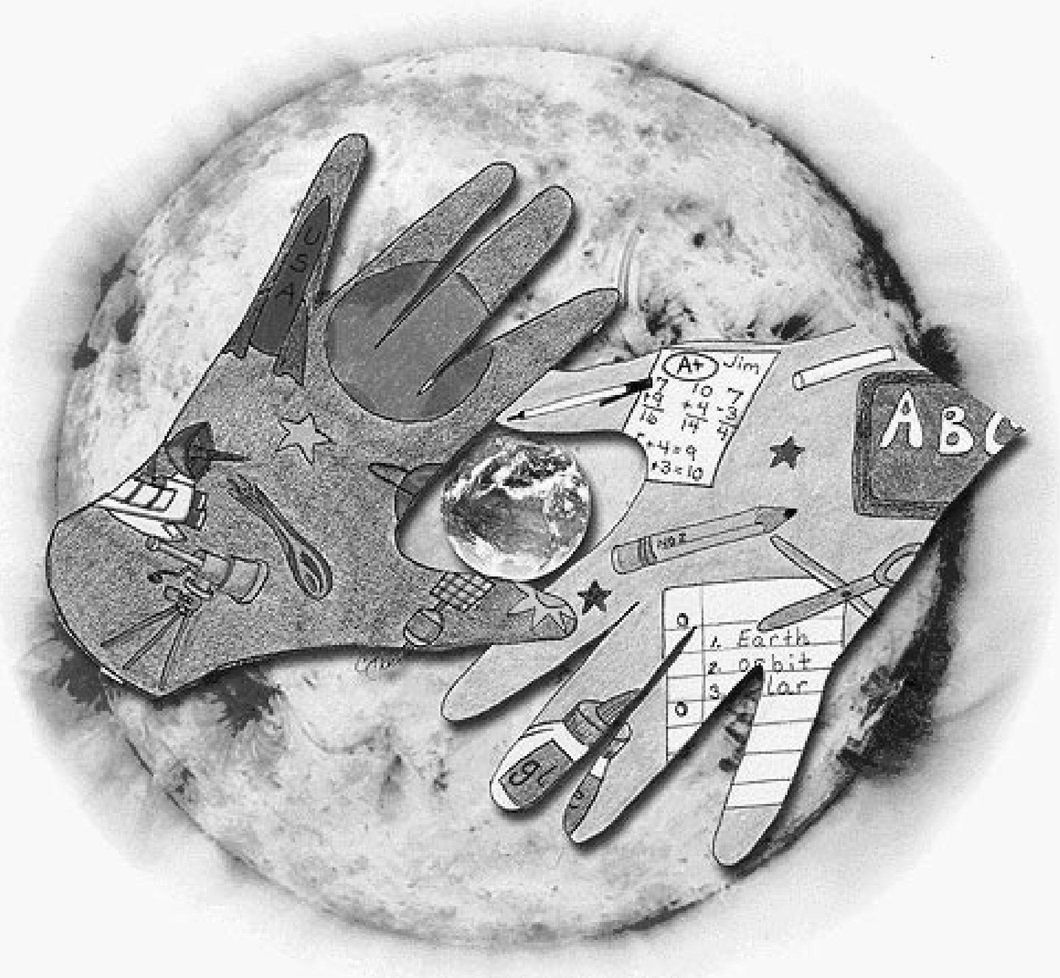
EG-2000-03-002-GSFC

Solar Storms and You!

Exploring Magnetic Storms

An Educator Guide with Activities in Space Science



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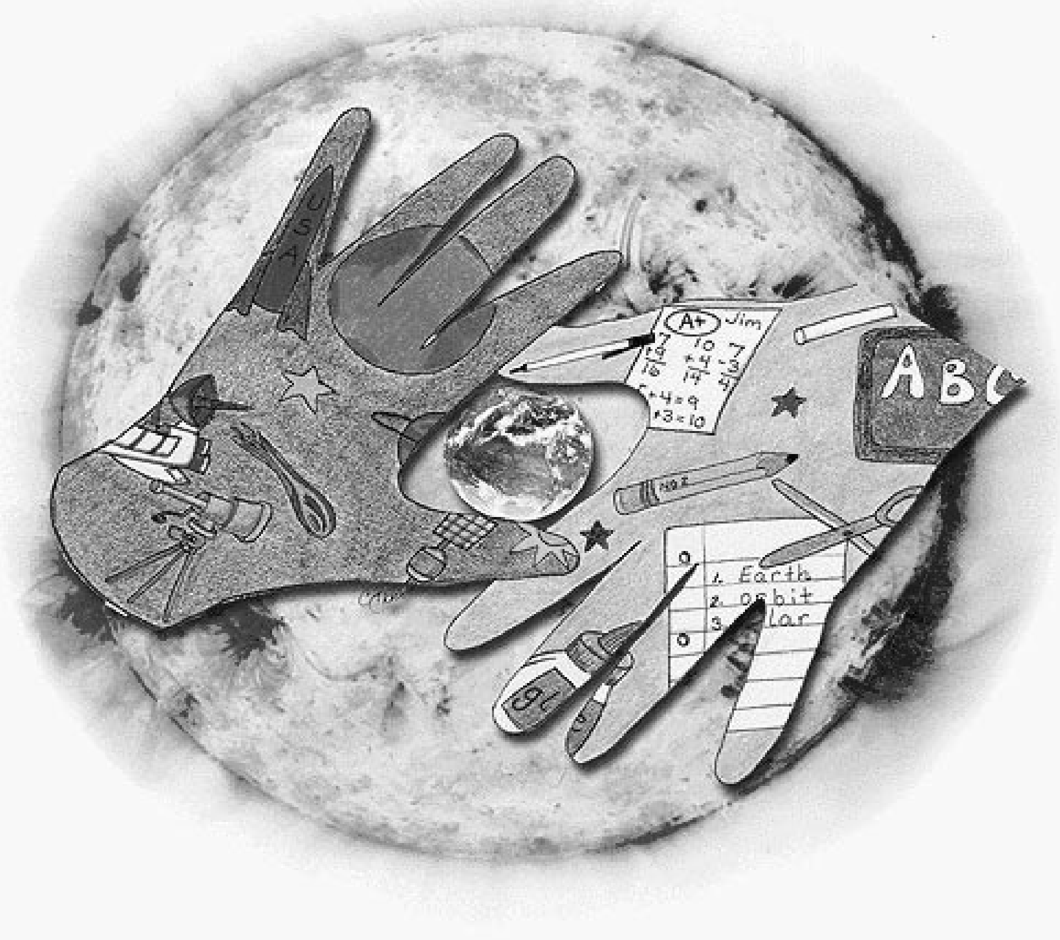

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Information about the IMAGE mission is available at:

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http://pluto.space.swri.edu/IMAGE

Resources for teachers and students are available at:

http://image.gsfc.nasa.gov/poetry

National Aeronautics and
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Goddard Space Flight Center

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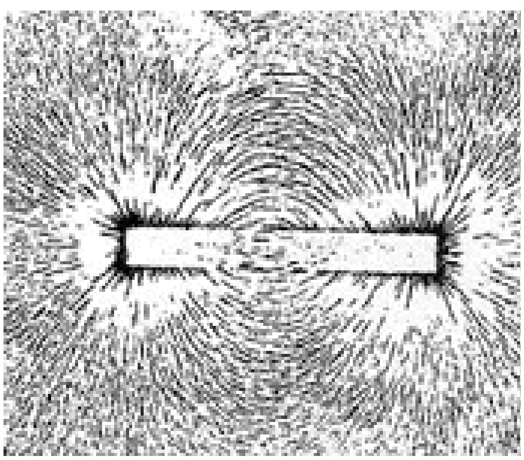
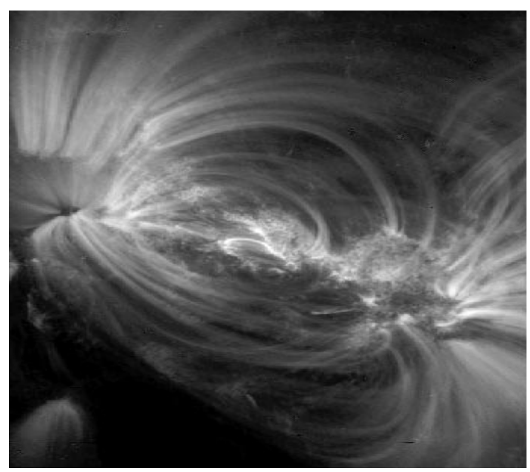




Powerful magnetic forces are responsible for most of the activity on the Sun. Without these fields, there would be no sunspots, prominences, and the solar corona would be a much cooler gas, no where near the 2 million degrees it is today. Magnetic fields are the same everywhere in the universe so far as we can tell. Compare the two pictures above. The photo on the left is iron filings near a toy bar magnet. On the right are the magnetic field lines near an active region on the Sun. Even though the sunspot field is nearly one trillion times larger than the toy magnet field...they look identical!

INTRODUCTION

A gas pipeline in Russia explodes
killing hundreds of people.

A satellite mysteriously falls silent
interrupting TV and cellular phone traffic.

A power blackout
throws millions of people into darkness.

These are only a few of the many things that solar storms can do when they arrive at the earth unexpected. In an age where we have increasingly come to rely upon the smooth operation of our technology, we have also made ourselves vulnerable to the ebb and flow of the solar storm cycle. Most people are not even aware this cycle exists, but long ago we used to be!

Ancient Chinese sun observers knew that, from time to time, dark spots would glide slowly across the face of the setting sun. Once seen only as portends of political upheaval, we now see them as natural phenomena that can forewarn us of impending storms that can have dire consequences for us if we ignore them.

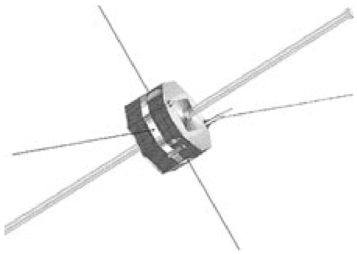
In this activity book, your students will study five key stages in the lifecycle of a solar storm, from its emergence on the solar surface to its impact upon some aspect of our lives. The book may be used in its entirety to study solar activity and how it directly affects us, or you may use individual activities of your choice as stand-alone mini lessons as an enrichment for math and physical science courses.

The student activities emphasize basic cognitive skills and higher-order processes such as plotting data, searching for patterns and correlations, and interpreting the results. By the end of the activity series, students will understand why we need to pay more attention to solar storms.

Visit the updated version of this workbook at:

http://image.gsfc.nasa.gov/poetry/workbook/workbook.html

Science Process Skills
for *Solar Storms and You!*

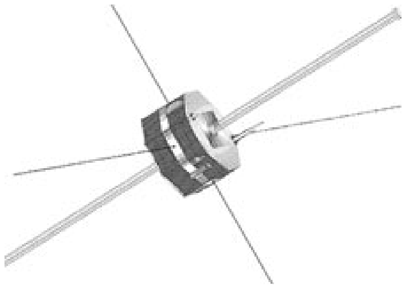


This chart is designed to assist teachers in integrating the activities contained in the guide with existing curricula.

	Lesson 1 *"Magnetic Storms from the Ground"*	**Lesson 2** *"Motion of the Magnetic Pole"*	**Lesson 3** *"A Soda Bottle Magnetometer"*
Observing	○	○	○
Classifying			
Communicating	○	○	○
Measuring	○	○	○
Inferring	○		
Predicting		○	
Experimental Design			○
Gathering Data			○
Organizing Data			○
Controlling Variables			○
Developing a Hypothesis	○		
Extending Senses			○
Researching		○	○
Team Work			○
Mathematics	○	○	○
Interdisciplinary			
Introductory Activity	○	○	○
Advanced Activity			

Science and Mathematics Standards

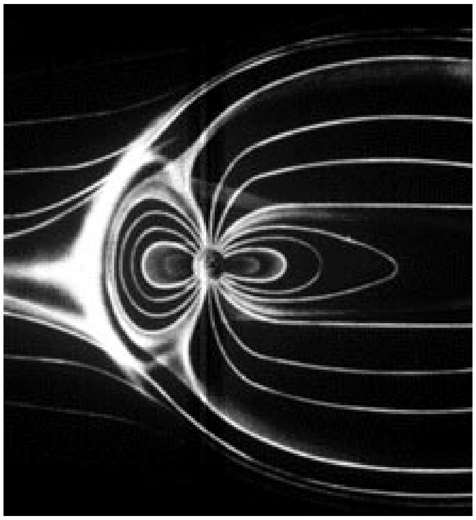
for *Solar Storms and You!*

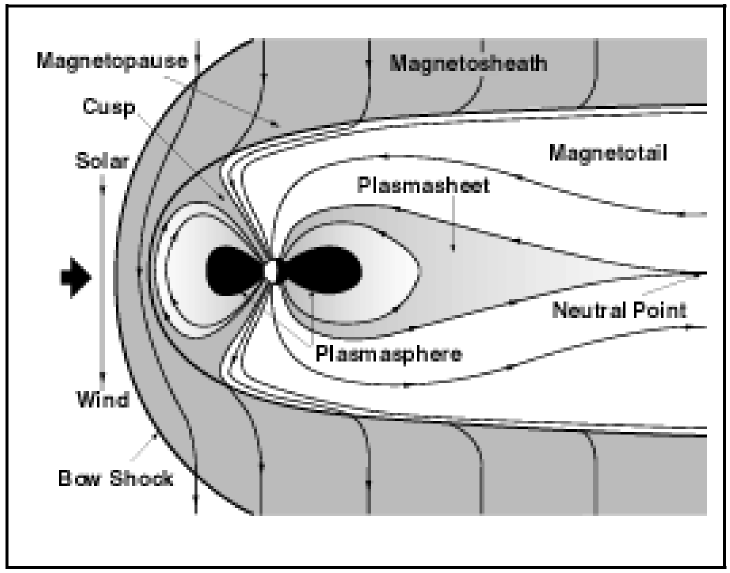


This chart is designed to assist teachers in integrating the activities contained in the guide with existing curicula.

	Lesson 1 *"Magnetic Storms from the Ground"*	**Lesson 2** *"Motion of the Magnetic Pole"*	**Lesson 3** *"A Soda Bottle Magneto-meter"*
Science as Inquiry	○	○	○
Structure and Energy of the Earth System	○	○	○
Origin and History of the Earth			
Earth in the Solar System	○	○	○
Geochemical Cycles			
Physical Science	○	○	○
Populations and Ecosystems			
Understanding Science and Technology	○	○	○
Science in Personal and Social Perspectives			
History and Nature of Science			
Problem Solving	○	○	○
Measurement	○	○	○
Computation and Estimation		○	○
Communication			○
Geometry and Advanced Mathematics		○	○
Statistics and Probability			○
Number and Number Relationships			
Patterns and Functions		○	○

Magnetic Storms





The Earth is the only one of the four inner planets (Mercury, Venus, Earth and Mars) that has a substantial magnetic field. Shaped very much like the field of a bar magnet, and powered by enormous currents of electricity in the molten core of the Earth, this field extends millions of kilometers into space to form the **magnetosphere**. Outside this region, charged particles from the Sun and deep space, may be deflected or may leak into the interior of this region to form the **Van Allen Belts,** or produce auroral activity.

This field changes in complex ways as CMEs find their way to the Earth and impact the magnetic field. Observatories on the ground have kept track of the strength and direction of the Earth's magnetic field for over a century. Their records show that rapidly changing field conditions are common, especially when the Sun is active.

The most dramatic of these episodes are called geomagnetic storms which can last several days. Less intense changes can last hours or minutes and are called geomagnetic sub-storms.

Navigation by compass is especially difficult during either of these magnetic storms because compass bearings can change by 10 degrees or more during the course of a few hours. As anyone familiar with using a map and compass can tell you, without knowing the 'magnetic deviation', it is impossible to use a compass to determine where geographic north is located. As a result, surface navigation can become dangerously imprecise.

Teacher's Guide

Magnetic Storms from the Ground

Introduction

Coronal Mass Ejections and other solar storms can buffet the magnetic field of the Earth with clouds of charged particles and magnetic fields. Not only do these interactions affect the large-scale properties of the geomagnetic field, but their affects can also be easily detected on the ground. During the last 100 years, many 'magnetic observatories' have been commissioned around the world to monitor the Earth's surface field conditions. These have been, historically, important for navigation by ships at sea. The data from these observatories can also be used to examine what happens when solar storms arrive at the Earth.

Objective

By analyzing graphical data, students will become familiar with the Earth's changing magnetic field through solar storm activity plots.

Procedure

1) Analyze the magnetic intensity plot for each station and identify the difference between stable activity, and the largest difference in change in activity (biggest peak) either positive or negative, on the plot. The units of magnetic intensity are in micro-Teslas, abbreviated as 'mT'.

2) Find the percentage change for each station. Round the answer to the nearest hundredth of a percent. Write the number below the location of the station on the map. See the Teacher's Answer Key.

3) Discuss and work the following questions and procedures:

—Where are the largest magnetic changes located for this event?

—Draw a circle around the three stations with the largest magnetic changes. Did the largest changes occur at the same time? Explain.

—On the Data Sheet, organize the plots in order from the largest to the smallest change. Do you see any patterns?

—Organize the magnetic intensity plots according to similar shapes. Are there any trends?

Materials

—5-station magnetic field Data Sheet.

—Calculator

—Map of Canada

Example: For Fort Churchill the normal 'stable' level was 59.3 mT and the largest deflection happened near 8:00 Universal Time (UT) at about 59.8 mT,

$$\% = 100 \times \frac{(\text{max} - \text{stable})}{\text{stable}}$$

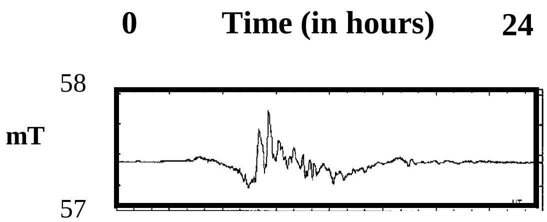
$$\% = 100\times \frac{(59.8-59.3)}{59.3}$$

or 0.85 percent.

Conclusion:

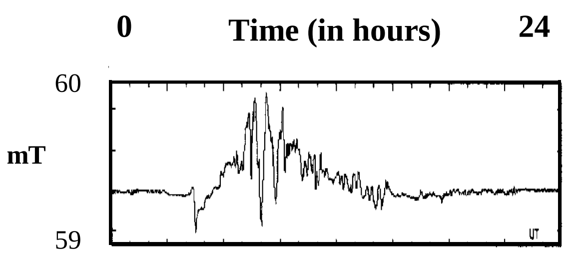
Students should have learned that the Earth's magnetic field does not remain constant in time, but can change its strength. By investigating and plotting data, students should have revealed the changes in intensity of the Earth's magnetic field due to solar storms. From this, students will locate those regions of the Earth that are most susceptible to solar storms.

Student Data Sheet



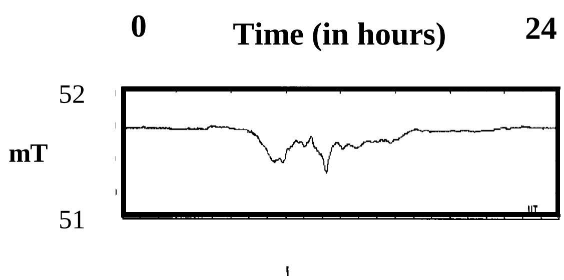
Station 1: **Meanook**
Latitude: **54.6 North** **Longitude:** **113.3 West**

Time: **Percent:**



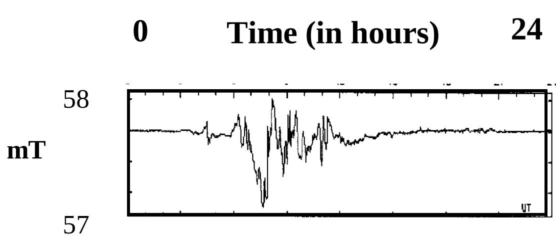
Station 2: **Fort Churchill**
Latitude: **58.8 North** **Longitude:** **94.1 West**

Time: **Percent:**



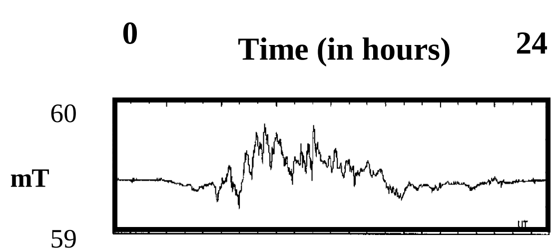
Station 3: **Victoria**
Latitude: **48.5 North** **Longitude:** **123.4 West**

Time: **Percent:**



Station 4: **Poste-de-la-Baleine**
Latitude: **55.3 North** **Longitude:** **77.8 West**

Time: **Percent:**



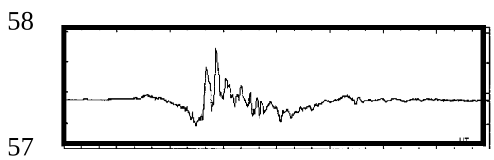
Station 5: **Yellowknife**
Latitude: **62.4 North** **Longitude:** **114.5 West**

Time: **Percent:**

Teacher's Answer Key

Note: Times given to 1/2 hour accuracy are adequate for this exercise. Percentages may vary by 0.1 percent depending on how students measure. Students may average their results for each station to produce a better 'class average' percentage.

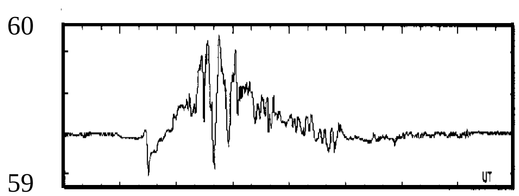
0 Time (in hours) 24



Station 1: **Meanook**

Latitude: **54.6 North** **Longitude:** **113.3 West**

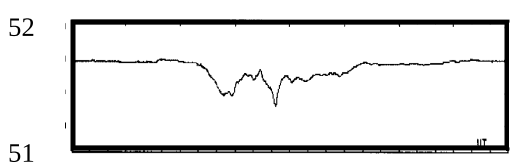
Time: **8:00** **Percent:** **0.70**



Station 2: **Fort Churchill**

Latitude: **58.8 North** **Longitude:** **94.1 West**

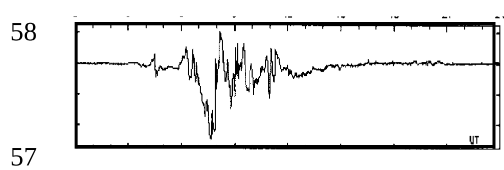
Time: **8:00** **Percent:** **0.85**



Station 3: **Victoria**

Latitude: **48.5 North** **Longitude:** **123.4 West**

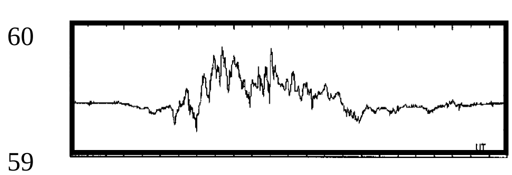
Time: **11:00** **Percent:** **0.58**



Station 4: **Poste-de-la-Baleine**

Latitude: **55.3 North** **Longitude:** **77.8 West**

Time: **7:30** **Percent:** **1.05**

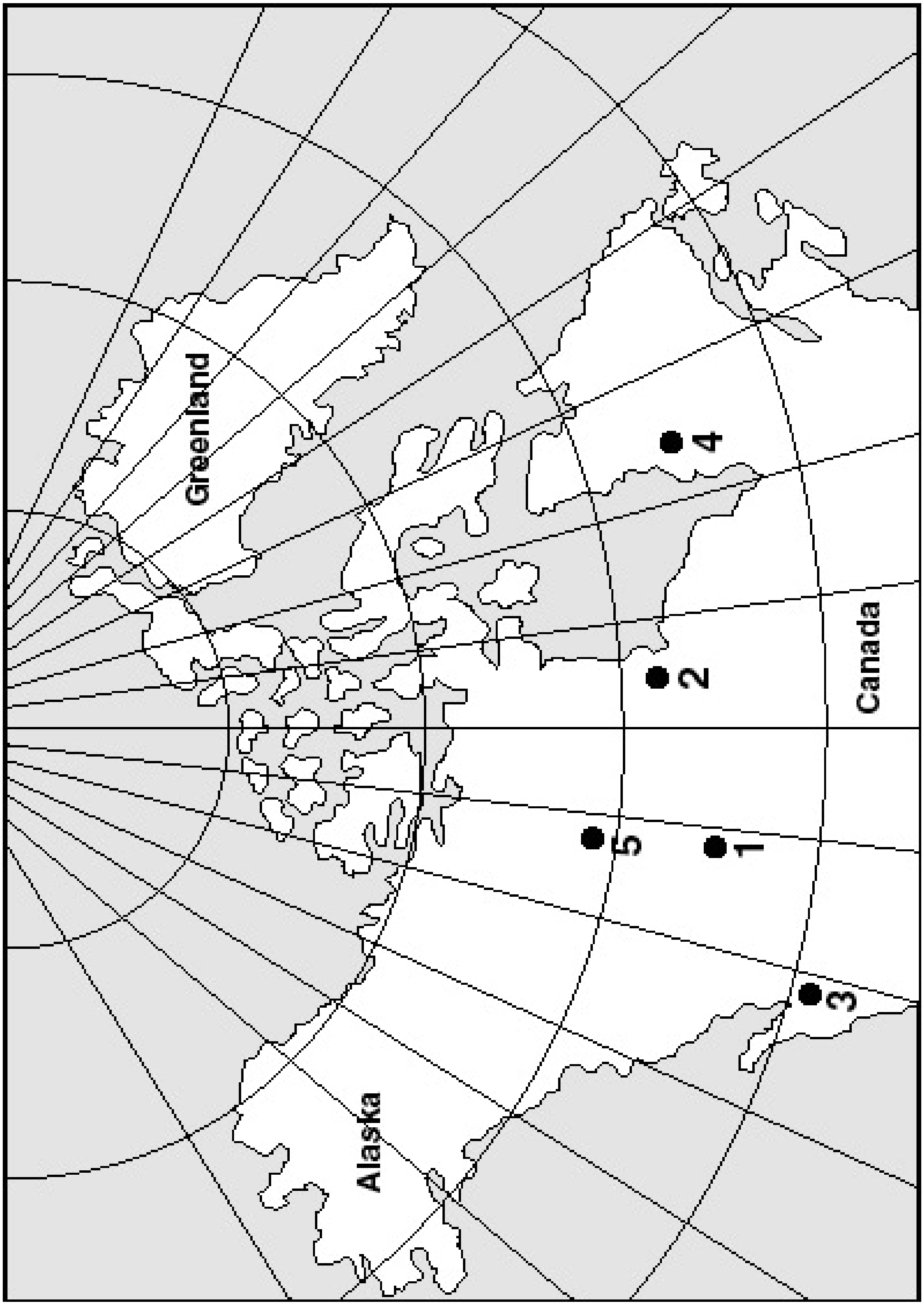


Station 5: **Yellowknife**

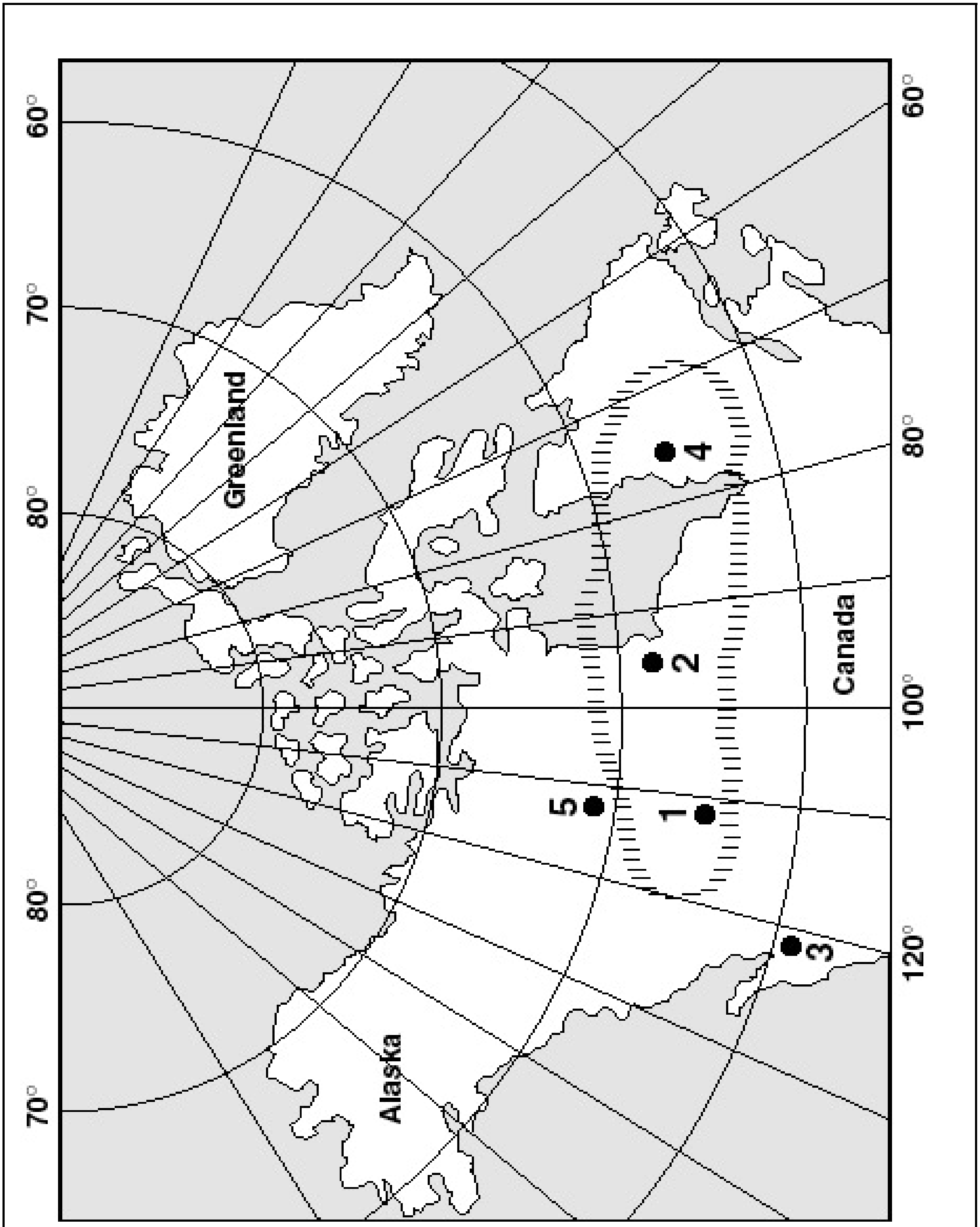
Latitude: **62.4 North** **Longitude:** **114.5 West**

Time: **8:00** **Percent:** **0.60**

Name ___________________________ Date_________________



Teacher's Answer Key



Teacher's Guide Motion of the Magnetic Pole

Introduction

The Magnetic North Pole has been charted over the past several hundred years. The pole shifts between 1 and 20 kilometers/year. Navigation by compass is especially difficult during a magnetic storm. Compass bearings can shift by 10 degrees or more within the course of a few hours, therefore, it is important to know the pole's present location.

Objective

The student will plot the latitude and longitude involved in the movement of the Magnetic North Pole over a period of time, predict its location by the year 2000, and justify their reasoning.

Procedure

1) Students will plot the latitude and the longitude for the given years using the data in the table.

2) Students will connect the points in the given order to see the pattern of movement in the Magnetic North Pole.

3) Students will measure the distances between the points, and using the time between the years in the table, arrive at an average rate of movement. (See explanation).

4) Students will plot and justify their choice of location based on their results. Student's prediction and justification should be based on the speed and the distance that the Magnetic North Pole has shifted in prior years.

EXPLANATION:

To calculate the speed, use the following formula:

$$\text{speed} = \frac{\text{Tabulated Distance}}{\text{Difference in Years}}$$

Example:

For the first interval between 1831 and 1904, the North Magnetic Pole moved 50 kilometers. The difference in the years is 1904-1831 = 73 years, so the speed during this interval is

$$\text{speed} = \frac{50}{73}$$

$$= 0.7 \text{ kilometers/year}$$

Materials

—Student Page
—Teacher Graph
—Ruler with millimeter units
—Calculator

Conclusion:

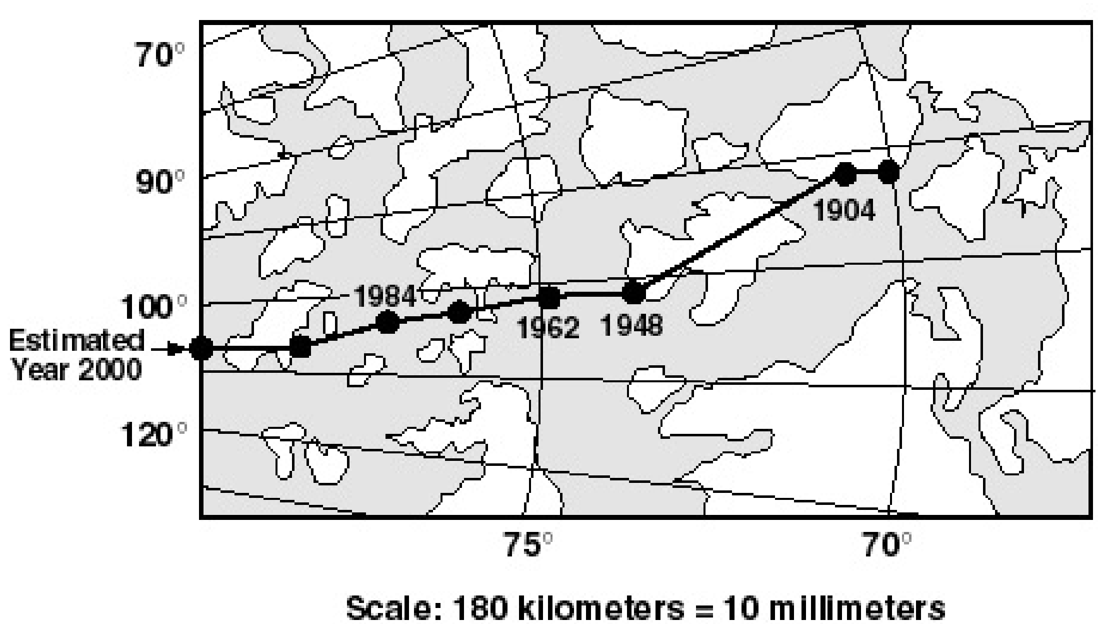
Students will understand that the Magnetic North Pole is not fixed at a specific geographic location, but moves from year to year by a significant amount.

Teacher's Answer Key

1. Plot the longitude and the latitude for the following years on the map below. NOTE: The distance that the Magnetic North Pole moved between the years has been calculated using the map scale.

YEAR	Longitude	Latitude	Distance	Speed (km/year)
1831	96.5	70.1		
1904	96.2	70.5	50 km	0.7 km/year
1948	101.1	73.8	420 km	9.5 km/year
1962	100.8	75.0	150 km	10.7 km/year
1973	101.3	76.1	120 km	10.9 km/year
1984	102.1	77.2	120 km	10.9 km/year
1994	104.0	78.5	180 km	18.0 km/year

2. Given the data in the table, plot a prediction for the location of the North Magnetic Pole for the year 2000.



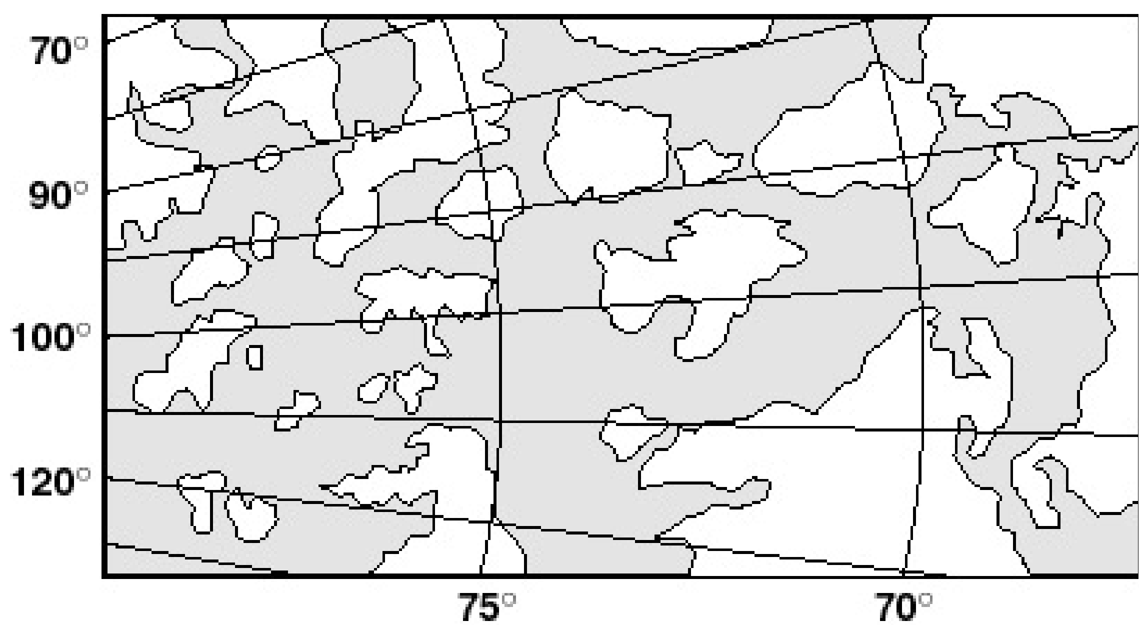
3. In your own words, justify the location of the prediction you have chosen.

The student prediction and justification should be based on the speed and the distance that the Magnetic North Pole has shifted in prior years. Students may either use an average speed based on the motion between 1831 to 1994 (= 1040 km/163 years = 6.4 kilometers/year) or may use the speed during the last 10 years (18.0 kilometers/year) but should justify which way they computed the speed. Either method is technically correct.

Name ____________________________   Date________________

1. Plot the longitude and the latitude for the following years on the map below. NOTE: The distance that the Magnetic North Pole moved between the years has been calculated using the map scale.

YEAR	Longitude	Latitude	Distance	Speed (km/year)
1831	96.5	70.1		
1904	96.2	70.5	50 km	
1948	101.1	73.8	420 km	
1962	100.8	75.0	150 km	
1973	101.3	76.1	120 km	
1984	102.1	77.2	120 km	
1994	104.0	78.5	180 km	



Scale: 180 kilometers = 10 millimeters

2. Given the data in the table, plot a prediction for the location of the North Magnetic Pole for the year 2000. Hint: Find the average rate of speed and complete the table. To calculate this for the given data, you will need to know that the speed is the distance the pole has moved divided by the difference between the two years in each interval . You may also decide to calculate the average speed for ALL of the time between 1831 and 1994. The units will be in kilometers/year.

3. In your own words, justify the location of the prediction you have chosen.

Teacher's Guide — A Soda Bottle Magnetometer

Introduction

Solar storms can affect the Earth's magnetic field causing small changes in its direction at the surface which are called magnetic storms. A magnetometer operates like a sensitive compass and senses these slight changes. The soda bottle magnetometer is a simple device that can be built for under $5.00 which will let students monitor these changes in the magnetic field that occur inside the classroom. When magnetic storms occur, you will see the direction that the magnet points change by several degrees within a few hours, and then return to its normal orientation pointing towards the magnetic north pole.

Objective

The students will create a magnetometer to monitor changes in the Earth's magnetic field for signs of magnetic storms.

Procedure

1) Clean the soda bottle thoroughly and remove labeling.

2) Slice the bottle 1/3 way from the top.

3) Pierce a small hole in the center of the cap.

4) Fill one quarter of the bottom section with sand.

5) Cut the index card so that it fits inside the bottle. (See Figure 1)

6) Glue the magnet to the center of the top edge of the card.

7) Glue a 1-inch piece of soda straw to the top of the magnet.

8) Glue the mirror spot to the front of the magnet.

9) Thread the thread through the soda straw and tie it into a small triangle with 2-inch sides.

10) Tie a 6-inch thread to top of the triangle in #9 and thread it through the hole in the cap.

11) Put the bottle top and bottom together so that the 'Sensor Card' is free to swing with the mirror spot above the seam. (See Figure 2)

12) Tape the bottle together and glue the thread through the cap in place.

13) Place the bottle on a level surface and point the lamp so that a reflected spot shows on a nearby wall about 2-meters away. Measure the changes in this spot position to detect magnetic storm events. (See Figure 3 and 4)

Materials

—One clean 2-liter soda bottle
—2 pounds of sand
—2 feet of sewing thread
—A small bar magnet
—A 3x5 index card
—A 1-inch piece of soda straw
—A mirrored dress sequin
—Super Glue (be careful!)
—2-inch clear packing tape
—A meter stick
—An adjustable high intensity lamp

Conclusion:

Just as students may be asked to monitor their classroom barometer for signs of bad weather approaching, this magnetometer will let students monitor the Earth's environment in space for signs of bad space weather caused by solar activity.

Conclusions and Tips:

Here are some tips you will find helpful.

It is important that when you adjust the location of the Sensor Card inside the bottle that its edges to not touch the inside of the bottle, and that the mirror spot is above the bottle seam and the taping region of this seam so that it is unobstructed and free to spin around the suspension thread.

The magnetometer must be placed in an undisturbed location of the classroom where you can also set up the high intensity lamp so that a reflected light spot can be cast on a wall within two meters of the center of the bottle. This allows a one-centimeter change in the light spot position to equal 1/4 degree in angular shift of the north magnetic pole. At half this distance, one centimeter will equal 1/2 degree. Because magnetic storms produce shifts up to 5 or more degrees for some geographic locations, you will not need to measure angular shifts smaller than 1/4 degrees. Typically, these magnetic storms last a few hours or less.

To begin a measuring session which could last for several months, note the location of the spot on the wall by a small pencil mark. Measure the magnetic activity from day to day by measuring the distance between this reference spot and the current spot whose position you will mark, and note with the date and the time of day. Measure the distance from the reference mark and the new spot in centimeters. Convert this into degrees of deflection for a two-meter distance, by multiplying by 1/4 degrees for each centimeter of displacement.

You can check that this magnetometer is working by comparing the card's pointing direction with an ordinary compass needle which should point parallel to the magnet in the soda bottle. You can also note this direction by marking the position of the light spot on the wall.

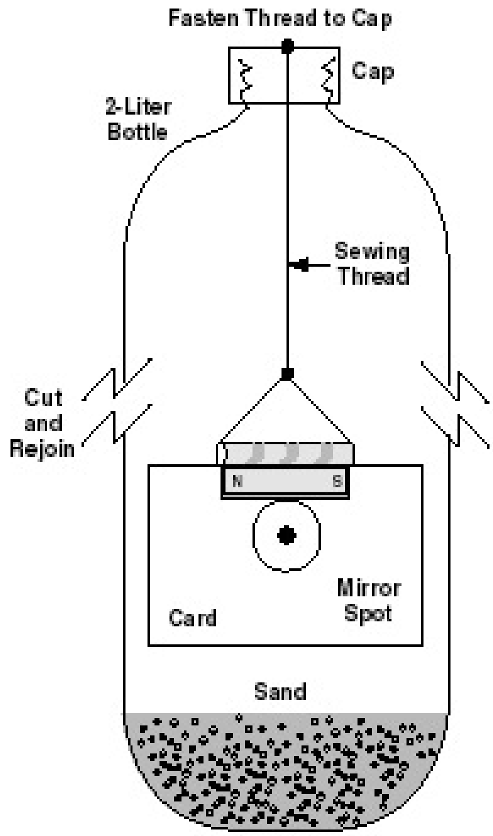
If you must move the soda bottle, you will have to note a new reference mark for the light spot and then resume measuring the new deflections from the new reference mark as before.

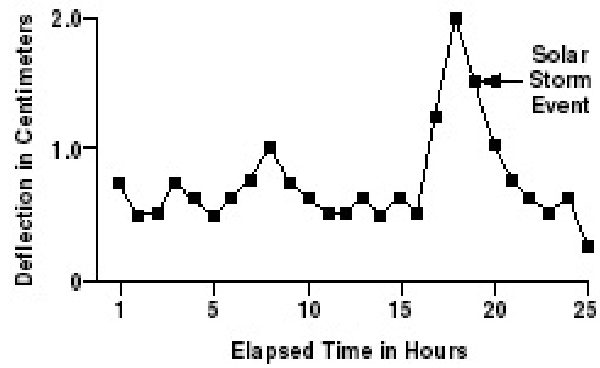
Most of the time there will be few detectable changes in the spot's location so you will have to exercise some patience. However, as we approach sunspot maximum in the year 2000 there should be several good storms each month, and perhaps as often as one a week. Large magnetic storms are accompanied by major auroral displays, so you may want to use your magnetometer in the day time to predict if you will see a good auroral display after sunset. Note: Professional photographers use a similar device to get ready for photographing aurora in Alaska and Canada.

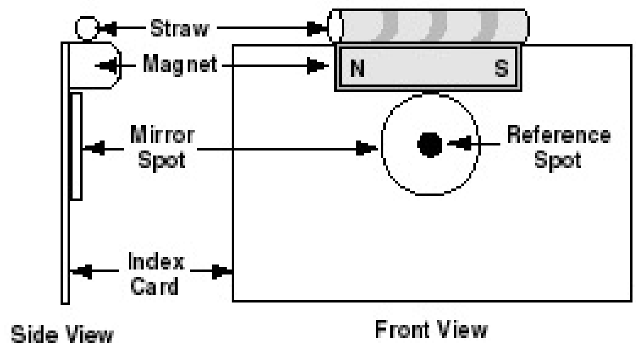
For more information about how to conduct this experiment, visit the NASA, IMAGE satellite web site's 'Join Magnet!' page at

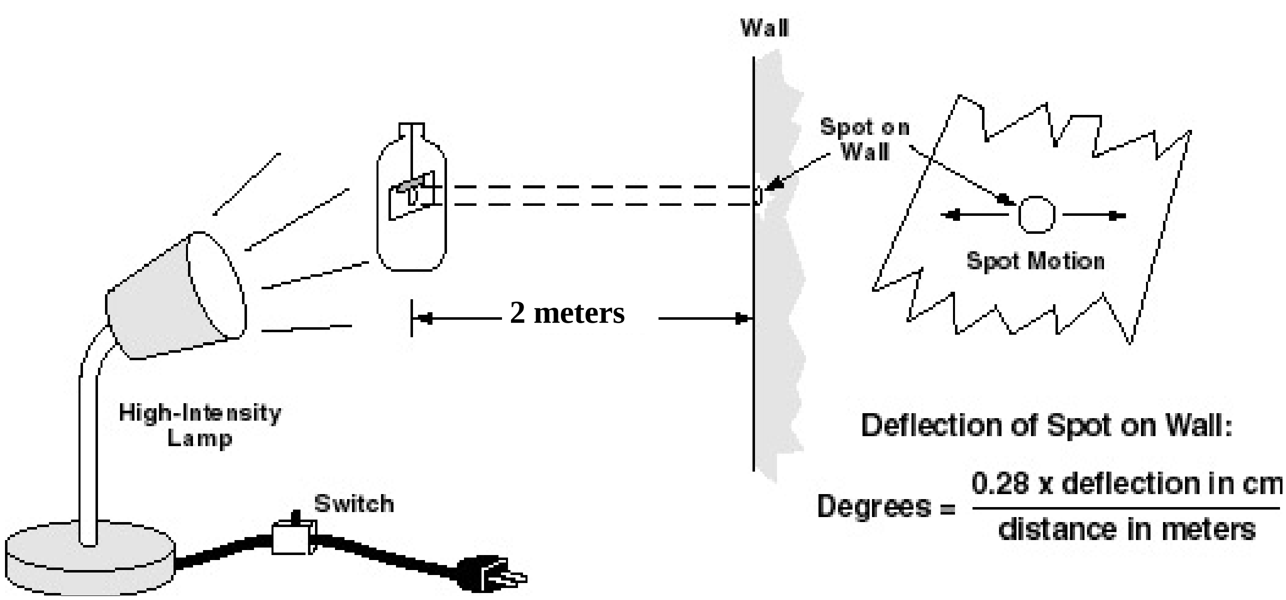
http://image.gsfc.nasa.gov/poetry

Plans for the Soda Bottle Magnetometer









What is Solar Activity?

The Sun, our nearest star, provides us with warmth and light. Many civilizations also thought the sun was it was a perfect orb, free of blemishes, eternal and changeless. **Sunspots** are the most well known hints that the Sun's surface is constantly changing. Larger than the Earth, and with magnetic fields that are 10,000 times stronger than the Earth's, sunspots are the breeding grounds for some of the most violent storms in the solar system!

The number of sunspots increases and decreases in cycles that last from 6 to 17 years; the **Sunspot Cycle.** With modern technology and space satellites, this solar activity cycle can now be detected in the ebb and flow of other phenomena on the Sun and on the Earth. Among the most enigmatic storms are the **solar flares** that erupt near sunspots. In a matter of 20 minutes, magnetic fields can heat gases to tens of thousands of degrees and release more energy than a thousand atomic bombs. Some of this gas can be hurled out from the Sun at millions of kilometers per hour in what are called **coronal mass ejections.** Both solar flares and coronal mass ejections can be very disruptive to human activity on earth and in space.

The outer atmosphere of the Sun, the **corona,** is familiar to many people who have watched total eclipses of the sun. The solar wind extends billions of kilometers further out into space than the corona**.** Like invisible roadways spanning the solar system, the magnetic field from the Sun flows out from the solar surface. Matter ejected from the Sun flows radially outwards from the solar surface. From the time a solar storm is seen on the Sun, it can take 2-3 days for the gas to travel to the orbit of the Earth, and if the Earth happens to be in the wrong place at the wrong time, it will be hit by a million-kilometer wide wall of high temperature gases and magnetic fields.

Anyone can tell you that a compass points 'north' because the Earth has a magnetic field, but until the advent of the Space Age, no one understood what this field really looked like or was capable of doing. Since Gilbert proposed in the 17th century that the Earth was a giant magnet, scientists have wondered just how this field is shaped, and how it has changed with time. The geomagnetic field which gives us our familiar compass bearings, also extends thousands of kilometers out into space in a region called the **magnetosphere**. On the Sun-side, it forms a protective boundary called the **bow shock.** Stretching millions of kilometers in the opposite direction behind the Earth is the **magnetotail.**

The solar wind blows upon the magnetosphere and gives it a wind-swept shape, but when solar storms and solar wind streams reach the Earth, the magnetosphere reacts violently. On the side nearest the impact, the magnetosphere compresses like squeezing a balloon, leaving communications satellites exposed. On the opposite side, it is stretched out, past the orbit of the Moon, or Mars and even Jupiter! The geomagnetic field is remarkably stiff, and so most of the solar wind is deflected or just slips by without notice. But some of the matter leaks in and takes up residence in donut-shaped clouds of trapped particles, or can penetrate to the atmosphere to produce aurora.

For thousands of years, humans have been treated to spectacles of glowing clouds above the northern horizon at night. Reports of these mysterious Northern Lights abound in the oral histories of the northern natives. On rare occasions, even ancient Greek and Chinese texts have mentioned them. It wasn't until 1896 that the Norwegian physicist Kristian Birkeland deduced that flows of electrons from the Sun were channeled into the polar regions by the geomagnetic field, and upon colliding with the outer atmosphere, would stimulate oxygen and nitrogen atoms to cast their ghostly and inspiring curtains of light.

The **Aurora Borealis** (near the north pole) and the **Aurora Australis** (near the south pole), as the 'Northern Lights' are more formally called, are seen most often in a band located at a latitude of 70 degrees, and about 10 degrees wide in latitude. From space, the auroral zone looks like a ghostly, glowing donut of light hovering over the north and south poles. This **auroral oval** can easily be seen in images from satellites designed to detect it. Its brightness and size change with the level of solar activity. Aurora come in many shapes and colors depending on what is happening to the geomagnetic field and the flows of charged particles and plasmas trapped in this field.

Magnetic sub-storms happen when the geomagnetic field is suddenly changed because of small changes in the magnetic polarity of the solar wind as it passes the Earth. Typically, magnetic storm aurora, also called **auroral storms,** last only a few hours. They begin in the evening as arcs of colored light which slowly change into rayed-arcs and the familiar folded ribbons or bands. Expanding over the whole sky, the folded bands are colorful, with green rays and red lower borders which change from minute to minute and move rapidly across the sky like some phantasmagoric serpent. After an hour, the auroral shapes become more diffuse and less distinct.

Geomagnetic storms are more severe than magnetic sub-storms and are caused by major changes in the direction and density of the solar wind as it reaches the Earth. These events are the most remembered historically as 'Great Aurora' or as the most disruptive to radio communications. The entire geomagnetic storm can last for several days as the particles and fields around the Earth continue to readjust themselves to the passing and ebbing solar wind.They begin with an ejection of mass by the Sun, and the impact of this plasma on the magnetosphere. Fast-moving coronal mass ejections produce shock waves in the solar wind, and this compression intensifies the density of particles impacting the magnetosphere. As the solar wind shock passes across the magnetosphere and magnetotail, magnetic fields re-orient and reconnect, releasing enormous amounts of energy and accelerating trapped particles to high speeds. These charged particles then travel down the geomagnetic field in huge currents, which cause bright and long lasting auroral displays.

Solar storms and the effects they produce in the Earth's environment, have been known for decades to be responsible for many harmful effects upon human technology on the ground and in space. Solar storms are known to do far more than just paint the sky with pretty colors! The multi-billion dollar 'Global Positioning System' consists of a constellation of over two dozen navigation satellites orbiting within the Van Allen radiation belts. These satellites let humans find their position anywhere on Earth using a hand-held receiver no bigger than a wrist watch.

During solar storms, these positions are quite a bit less accurate than under calm conditions, which in turn impacts the navigation of ships at sea and jets in the air. Solar storms have disabled multi-million dollar communication and navigation satellites such as Anik-A, Molynia, Marecs-A, and they have been implicated in many electrical problems that were experienced by other satellites.

Solar storms were responsible for causing the Skylab to burn up in the atmosphere sooner than expected, and for altering the orbits of hundreds of other satellites and even the Space Shuttle itself. A storm on March 13, 1989 knocked out the Quebec-Hydro power system, plunging 6 million people into darkness for 9 hours. Geomagnetic storms cause the magnetic field near the Earth's surface to change rapidly in just a matter of minutes or hours. These changes cause electrical currents to flow within long power transmission lines, telephone wires, and even in pipelines which makes the pipes corrode, sometimes with tragic consequences. On June 5, 1991 a natural gas pipeline in Russia was weakened by corrosion and began to leak its deadly, flammable cargo. A passenger train, loaded with 1,200 people, ignited the liquefied gas and caused an explosion equal to 10,000 tons of TNT. Over 500 people were killed, and 700 more were badly injured.

Would you believe...

Aurora can never get closer to the ground than about 60 kilometers.

A sunspot has a temperature of nearly 4000 C, and would be brighter than the full moon if placed in the night sky.

Sunspots are often several times larger than the entire earth.

The Sun rotates once every 25 days at the equator, but takes up to 36 days to rotate once around at the poles.

The corona of the Sun is over 5 million degrees hotter than the surface of the Sun.

The Earth's magnetic north pole is actually a magnetic south pole because the north end of a bar magnet is attracted to it.

The total power produced by an auroral event can exceed 1 million megawatts and produce voltages over 100,000 volts in the upper atmosphere.

Aurora are produced where the atmosphere has the same density as the vacuum inside a light bulb.

Some aurora occur at altitudes of over 1000 kilometers above the Earth's surface.

Lightning storms can eject particles into space at nearly the speed of light, and they are seen as 'sprites' on the top side of a thundercloud.

A single lightning storm can be detected on the other side of the earth because some of its radio energy travels along the local magnetic field lines that connect the pairs of points on the surface of the Earth that can be thousands of kilometers apart.

Glossary

Aurora : Also called the 'Northern Lights' in the Northern hemisphere, or the 'Southern Lights' in the Southern hemisphere. These wispy curtains of light in the sky are caused by energetic electrons which collide with atoms of oxygen and nitrogen in the air to cause these atoms to emit shades of green, red and blue light. They never descend nearer than 60 kilometers from the Earth's surface.

Corona : The very tenuous outer layers of the Sun which are seen during a total eclipse of the sun, but extending millions of miles into interplanetary space. It is heated to temperatures of over one million degrees by magnetic activity at the surface of the Sun. For decades, scientists puzzled over why the Corona could be so much hotter than the balmy 5770 degree Kelvin surface of the Sun.

Coronal Mass Ejection : The sudden expulsion of matter from the coronal regions of the sun, often involving billions of tons of plasma ejected at over one million kilometers per hour. During sunspot minimum conditions, about one 'CME' can be expelled every few days. During sunspot maximum conditions, as many as 3-5 can occur each day.

Magnetopause : A region that defines the outer edge of the magnetosphere where the pressure of the solar wind is balanced by the pressure of the earth's own magnetic field.

Magnetosphere : The region surrounding the Earth in space where its magnetic field is important in controlling the movements of charged particles. Also sometimes referred to as 'Geospace'.

Magnetotail : The solar wind pulls the magnetosphere into a comet-like shape. The long tail of this field, called the magnetotail' or also the 'geotail', extends millions of miles into space in a direction opposite to the Sun from the Earth.

Solar flare : A powerful release of energy on the surface of the sun usually lasting less than a few hours, but releasing as much energy as 1000 hydrogen bombs. These are often associated with active regions of the solar surface where magnetic fields have become badly tangled, and then snap, releasing energy and heating local gases to over 1 million degrees.

Solar storm : Although scientists prefer not to use this term because it is technically rather vague, it has come to mean any of a number of active conditions on the Sun's surface including flare activity or coronal mass ejections.

Sunspot : A dark spot on the Sun's surface that indicates a concentration of magnetic forces. They are actually about 2000 degrees cooler than the solar surface, and only look dark because they emit light faintly.

Sunspot Cycle : The change in the number of sunspots from one period of its maximum to the next, over the course of about 11 years.

Sunspot Maximum : The period during the sunspot cycle when you will see the largest number of sunspots. Also called the 'Solar Maximum'.

Sunspot Minimum: The period during the sunspot cycle when you will see the fewest number of sunspots. Also called the 'Solar Minimum'

Resources

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The Earth's Magnetic Field	http://image.gsfc.nasa.gov/poetry/magneto.html
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Magnetic North Pole	http://www.nrcan.gc.ca/gsc/cpdnew/magnet.html
Solar Sounds	http://soi.stanford.edu/results/sounds.html
Sunspot Number Archives / Resources	http://image.gsfc.nasa.gov/poetry/sunspots.html
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Stellar Activity Cycles at Mt. Wilson	http://www.mtwilson.edu/Science/HK_Project/
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Space Weather Resources	http://image.gsfc.nasa.gov/poetry/weather.html
Magnetic Observatories and Data	http://image.gsfc.nasa.gov/poetry/maglab/magobs.html
Space Environments and Effects	http://see.msfc.nasa.gov/sparkman/Section_Docs/sparkman.html
Sun-Earth Classroom Activities Archive	http://sunearth.gsfc.nasa.gov/educators/class.html
Storms from the Sun	http://www.istp.gsfc.nasa.gov/istp/outreach/learn.html
The Aurora Page	http://www.geo.mtu.edu/weather/aurora/
Space Weather Human Impacts	http://image.gsfc.nasa.gov/poetry/storm/storms.html
Ionosphere density and sunspot numbers	http://julius.ngdc.noaa.gov:8080/production/html/IONO/ionocontour_90.html
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