Geomagnetism in the MESA Classroom:
An Essential Science for Modern Society
Student Guide

NAME: ______________________________________

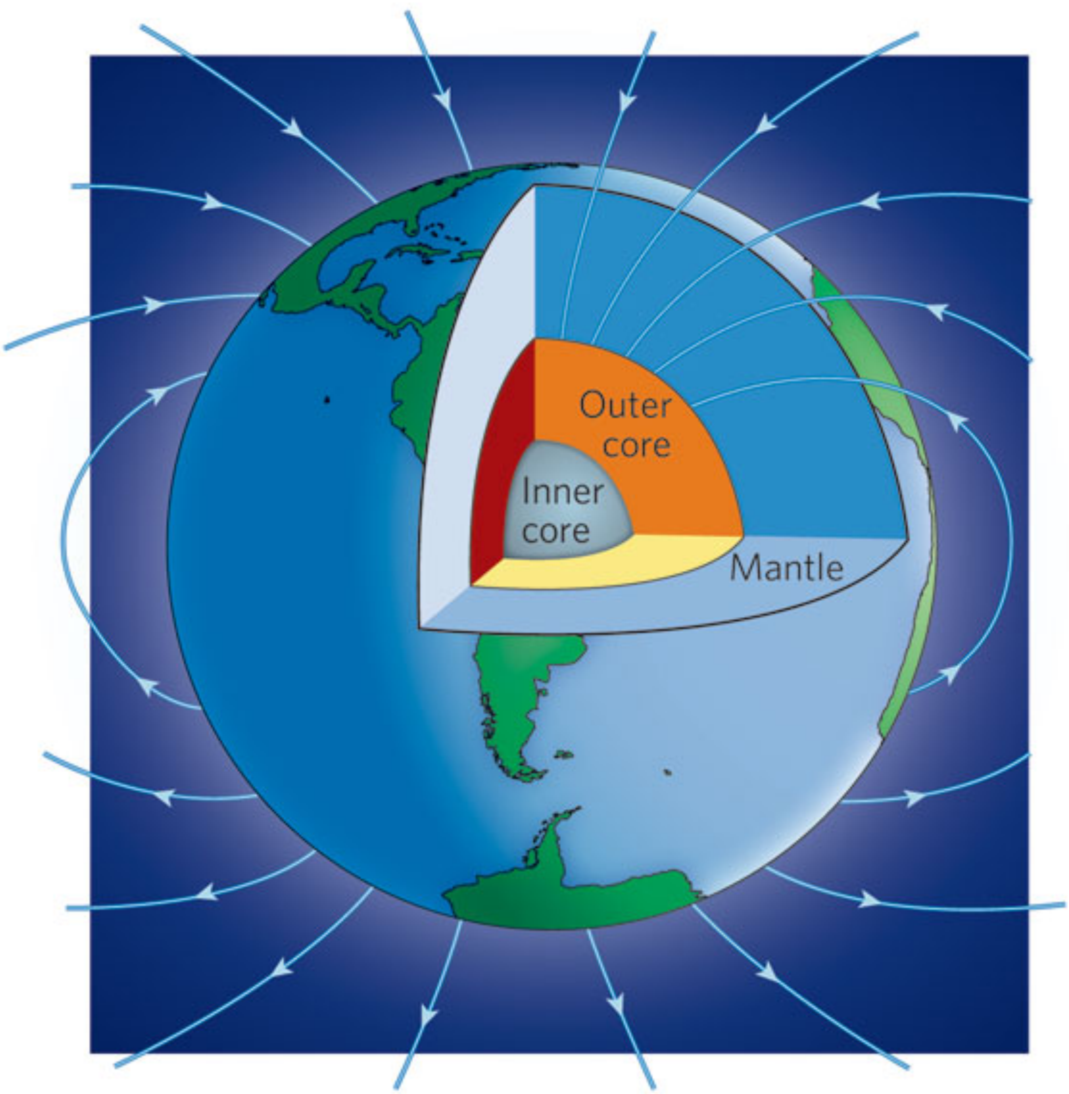

Image source: Earth science: Geomagnetic reversals
David Gubbins, Nature 452, 165-167(13 March 2008), doi:10.1038/452165a

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University of Colorado

CIRES

University of Colorado Boulder

Overview:

The Cooperative Institute for Research in Environmental Sciences (CIRES) Education Outreach's GeoMag kit is a four-part after-school module that explores geomagnetism with compasses, navigation exercises, and a geo-caching activity, followed by a field trip to the National Oceanic and Atmospheric Administration's David Skaggs Research Center in Boulder.

Sound like fun? We hope that you will have a great time working on these lessons. We want to help you answer a few essential questions.

Session One:

What are some characteristics of Earth's magnetic field?
How to we use Earth's magnetic field in navigation?

Session Two:

How do we navigate without a GPS?
What is geocaching?

Session Three:

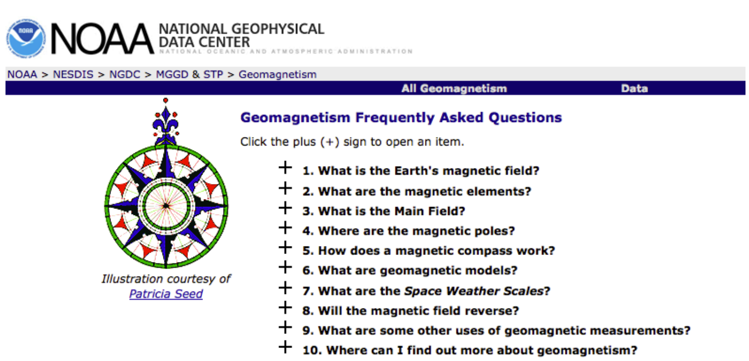
What causes an aurora?
How are Earth's magnetic field and aurora related?
What is space weather?

Session Four:

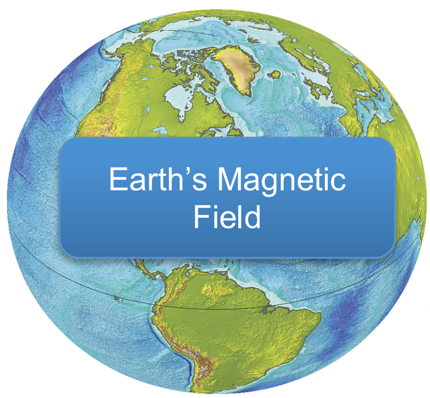
How do the scientists at NOAA's Space Weather Prediction Center use space weather data and information?

The study of geomagnetism is one of the oldest of the geophysical sciences. NOAA's National Geophysical data center studies the earth's magnetic field. They have a great question and answer website so you might want to visit it some time!

Here is the link: http://www.ngdc.noaa.gov/geomag/



What do you know about Earth's magnetic field? Create a concept of what you know about Earth's magnetic field. Write down any questions you have in the section below and answer the question; what does a compass do at the North Pole?



What would a compass point to is you were at the North Pole?

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!! WARNING !! Iron filings are messy and will stick to magnets. It is important to have paper or transparencies between the filings and the magnets.

Exploring Magnetic Field Lines

Procedure: Place the paper on top of one of you bar magnet, trace the outline of the bar magnet and mark which end is North and which is South. Lightly sprinkle the iron filings uniformly over the paper and then give the paper some gentle taps to make the filings align with the magnetic field.

Questions: On another sheet of paper answer the following questions.

1. What did you observe when you sprinkled the iron filings over the paper covering the bar magnet? Draw what you observed.

2. Can you explain why the iron filings behaved that way?

3. Draw what you expect to see when you sprinkle iron filings over two bar magnets in a new configuration.

The Dynamo Effect:

The Earth's magnetic field is attributed to a dynamo effect of circulating electric current, but it is not constant in direction. Rock specimens of different age in similar locations have different directions of permanent magnetization. Evidence for 171 magnetic field reversals during the past 71 million years has been reported.

Although the details of the dynamo effect are not known in detail, the rotation of the Earth plays a part in generating the currents, which are presumed to be the source of the magnetic field.

Source: http://hyperphysics.phy-astr.gsu.edu/hbase/magnetic/magearth.html

4. Draw what you did, in fact, see with your two magnets in the new configuration. How were your expectations the same or different?

Clean Up: Lift up the paper carefully so as to not spill any of the filings, and funnel them back into your filings jar.

This handout will help you explain navigating with Earth's magnetic field and Earth's geographical axis. Read and discuss this article with your group. Then as a group create a model to explain declination. You may wish to use other resources as well. Be ready to teach the other students in your class what you have learned about Earth's magnetic field.

There are two North Poles:

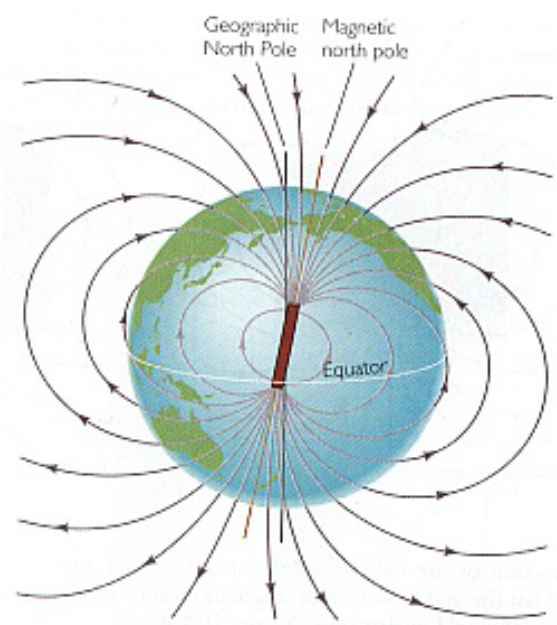
The first is the Geographic (or True) North Pole:

- The point toward which all north directions point.
- The location where the north end of the Earth's rotation axis emerges from the earth.
- It is defined as 90°N
- It is located in the middle of the Arctic Ocean

The second is the Magnetic North Pole

- It is the point that a magnetic compass points to.
- It is presently located in Canadian Territorial waters, west of Greenland. It is slowly moving in a north-westerly direction across the Arctic Ocean. It is estimated that it is moving at a speed of about 40 kilometers per year and over the last century the Magnetic Pole has moved a remarkable 1100 kilometers.
- This magnetic attraction and movement is a result of the magnetic forces within the Earth.

Finally, there are also **two South Poles** – Geographic and Magnetic. The Magnetic South Pole is magnetic, but this is very weak and hard to identify even if you are near it, as a result magnetic compasses rarely point to the South Magnetic Pole.



The difference in direction between true north and magnetic north, called declination in maps and variation in nautical charts, differs from place to place and year to year because Earth's magnetic field shifts over time. Most topographic maps graphically represent the directions to true and magnetic north in their legend, including the angle of declination for that position. Most nautical charts graphically represent the directions to true and magnetic north, plus the local variation, in the form of a printed compass dial called a compass rose. When translating from map to compass, add the number of degrees of west declination. Subtract east declination. When going from compass to map, just reverse, adding east declination, and subtracting west.

TRUE NORTH = MAGNETIC NORTH ± (DECLINATION)

From http://www.essortment.com/hobbies/compassnavigati_secc.htm

Declination

In the picture of the Earth to the right, you can see that the magnetic north pole is in a different place from the geographic north pole (the axis along which the Earth spins).

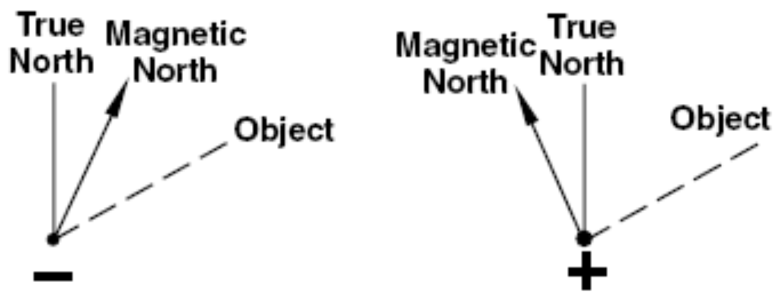
A compass will align itself with the Earth's magnetic field, not the geographic pole. The direction in which the compass needle points is known as Magnetic North, and the angle between Magnetic North and the True North direction is called **magnetic declination**.

The method for correcting for declination is as follows:

1. For Easterly Declination, subtract the declination from the true reading to obtain the magnetic reading. Magnetic = true - easterly declination

2. For Westerly Declination, add the declination to the true reading to obtain the magnetic reading. Magnetic = true + westerly declination

An easy way to remember whether to add or subtract is "West is best and East is least." So for West declination, add to the true reading (West is best, and therefore a larger number) and for East declination subtract from the true reading (East is least, and therefore a smaller number).

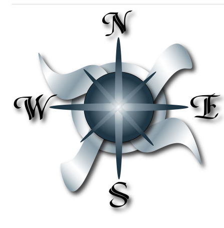


If the arrow *on the compass* is to the right of *true north*, or to the east, **subtract** the declination.

If the arrow *on the compass* is to the left of *true north*, or to the west, **add** the declination.

On the map below, the declinations for the United States are shown. To calculate a true direction in the United States, take the heading and either add the declination (for West Declination) or subtract it (for East Declination) from your desired heading. This will be the magnetic heading you want to follow.

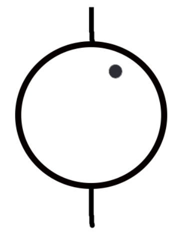
Let’s make a Teaching Model:



Materials Needed:
Styrofoam ball
Toothpicks
Marker

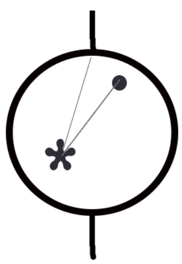
Procedure:

Take a Styrofoam ball and place two toothpicks in it. One at the top and one directly underneath. The toothpicks will represent the Geographic North and South poles.



Next use a marker and place a dot near the north pole to represent the Magnetic North Pole. See the image at the right for reference.

Now choose a location that is about in the middle of the ball. Draw a line from the pole to your location and from the location to the magnetic north position.



See the image at the left for reference.

Determine if the declination is easterly or westerly. You may review the information above for a more in-depth explanation.

Now use your model to teach your classmates about easterly and westerly declination.

Questions to Consider:

Why do USA cities on the east coast have a westerly declination?

Why do USA cities on the west coast have an easterly declination?

TRUE or FALSE: The States of Florida, Georgia and Kentucky will always have a westerly declination.

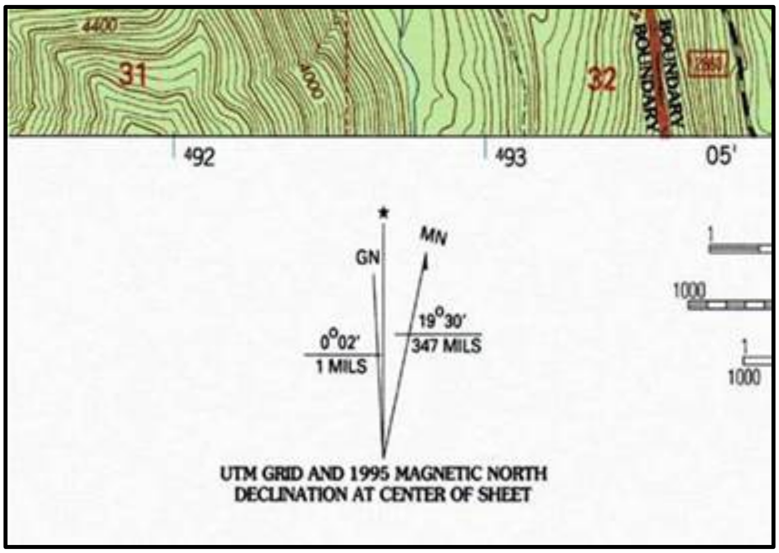
What questions does your group have about declination?

Extension:

If you have time and would like to create a small earth model for this activity with a tennis ball instead of the Styrofoam ball, use the following link to download a great map from EarthKam.
https://earthkam.ucsd.edu/files/pdf/GeoCreateATennisBallGlobe.pdf

This handout will help you understand that Earth's magnetic field changes over time. Read and discuss this article with your group. Then as a group explore NOAA's historic declination calculator. Be ready to teach the other students in your class what you have learned about Earth's magnetic field.

Magnetic declination for a location is often printed on a topographic map or navigation chart. These values, however, are not always accurate because the magnetic field changes over time. Check out the picture on the left of a topo map. Notice the date? Topo maps are updated regularly so it is important to look at the date and use the latest version of map available so when you are using a compass and navigating, you will be able to know where you are and where you are heading. You could get lost from using an outdated map if you only navigated with a compass.

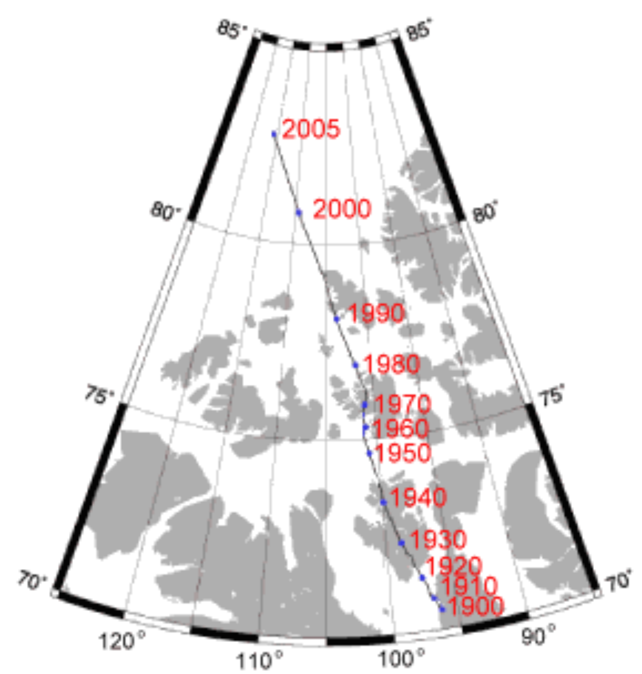


Read on to discover how the magnetic field changes over time.

The map to the right shows where the north magnetic pole was from 1900 through 2005. Why does it move? Exactly how this happens isn't widely understood, but it is thought to be due to change in the rate of spin of the Earth's core and the currents in the molten outer core.

Another feature of the geomagnetic field is that over long periods of time, the North and South Magnetic Poles switch positions. It is believed this happens over months or years and might have only very mild effects to organisms living on the earth.

The popular notion of a "pole shift" is certainly a documented fact with regard to the magnetic poles, but not with regard to the geographic poles of rotation. There is no scientific evidence for the planet physically flipping upside down.



Movement of the North Pole in Northern Canada

A compass in Fairbanks would have pointed along line #2 in 1900 to what was then the north magnetic pole, but it would point along line #1, near the present magnetic pole, in 2005.

A compass in Winnepeg would have pointed along line #4 in 1900 to where the magnetic pole was at the time. It would have pointed along line #3, near the present magnetic pole, in 2005.

As you see, the declination can change quite a bit over time, depending on where you are and what year it is. Using an old map or chart can be risky since the declination it gives you may be decades out of date.

Image source: www.compassdude.com/compass-declination.shtml

Fun Fact:

Airport runways are designated according to the points on a compass.

Runway Designators. Runway numbers and letters are determined from the approach direction. The runway number is the whole number nearest one-tenth the magnetic azimuth of the centerline of the runway, measured clockwise from the magnetic north. The letters, differentiate between left (L), right (R), for parallel runways.

Travelers have struggled with the complexity of navigating by compass for centuries, and modern American travelers are no exception. The magnetic poles don't line up with the geographic ones, and the difference between them is an angle called declination. As if this wasn't enough of a nuisance for navigators, the Earth's magnetic field drifts, causing the angle of declination to change over time.

So the drifting magnetic north means that airport runways, periodically, need to be renamed.

Historic Declination

Want to see how the declination has changed over the years? Want to compare how it has changed in the last 10, 25, 50 or even 100 years? Check out the Historic Declination tab and record your findings.

http://www.ngdc.noaa.gov/geomag-web/#declination

US Historic Declination	
Location you chose:	
Latitude:	
Longitude:	
Year	**Declination (+ E | - W)**

This handout will help you discover what the magnetic declination is for a specific location. You will use the online magnetic declination calculator provided by the National Geophysical Data Center in Boulder, CO.

To use the online magnetic declination calculator provided by the National Geophysical Data Center, you enter the zip code or latitude/longitude of a location and the date you want it for, and the calculator will provide you with the declination.

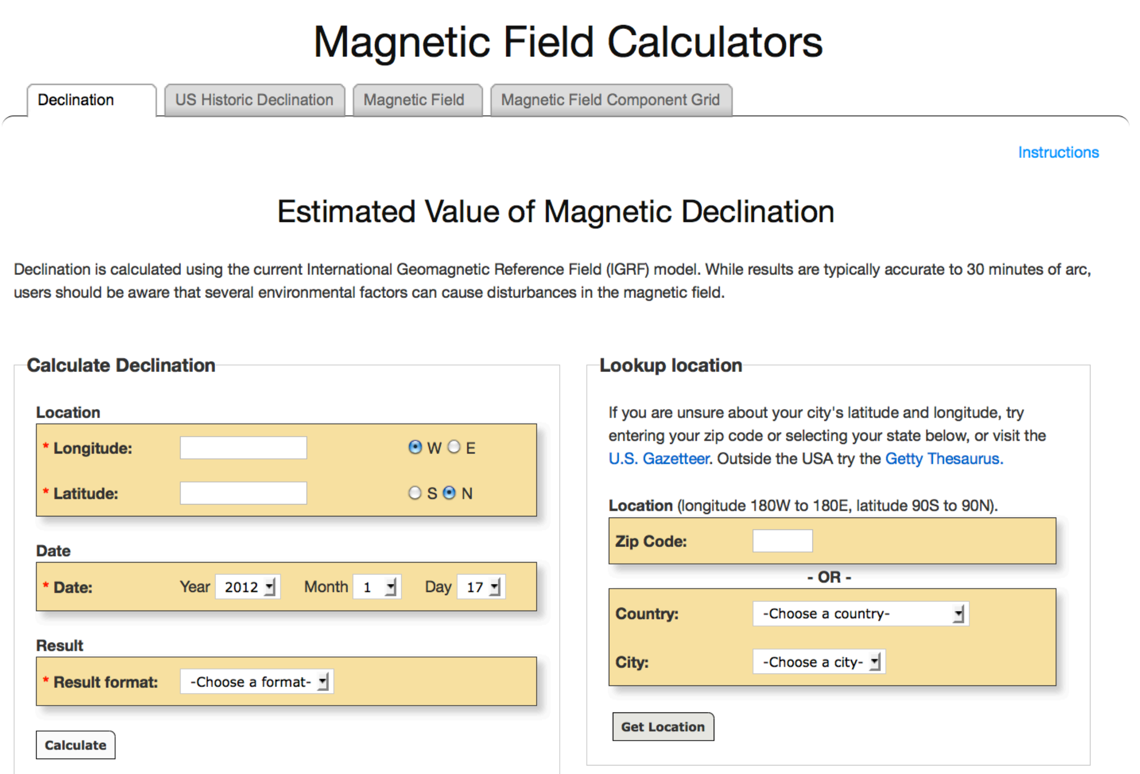
URL: http://www.ngdc.noaa.gov/geomag-web/#declination

For example, here are the zip codes for three airports that we'll use in our navigation exercise:

Los Angeles, CA (LAX)—90045
Chicago, IL (ORD)—60666
Jamaica, NY (JFK)—11430

The declinations for 2013 are as follows:

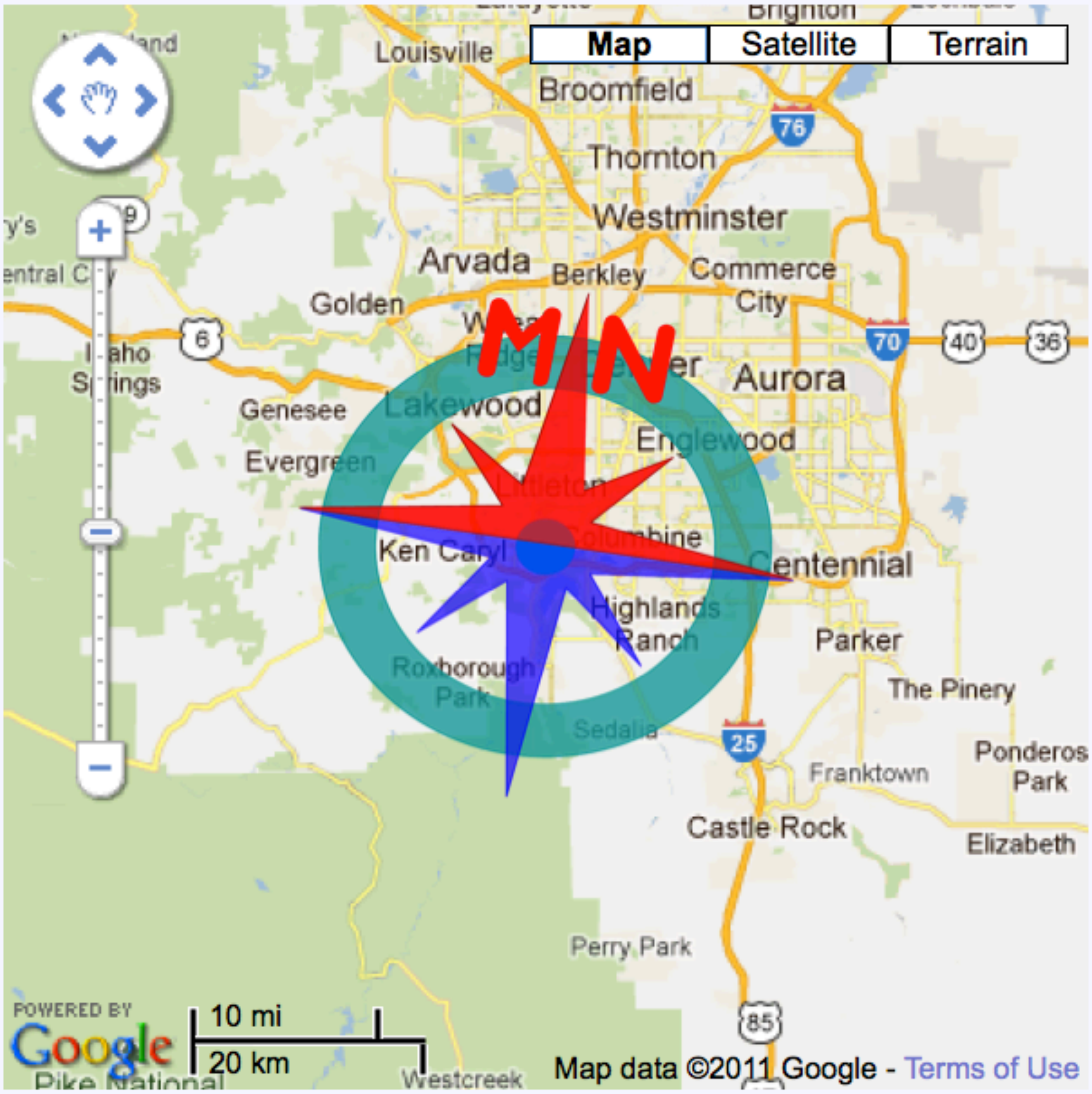
LAX: 12 degrees 27 minutes E
ORD: -3 degrees 40 minutes W
JFK: -13 degrees 6 minutes W



National Geophysical Data Center Declination Calculator

Declination

Longitude:	105° 4' 44.40857" W
Latitude:	39° 34' 40.79681" N
Date	**Declination (+ E | - W)**
2012-01-17	8° 52' 45.94734"



Check out the declination for several US state capitols and major cities.
Use the NOAA declination calculator
http://www.ngdc.noaa.gov/geomag-web/#declination

US Cities Declination	
US City	**Declination (+ E | - W)**
Sacramento, CA	
Carson City, NV	
Salt Lake City, UT	
Cheyenne, WY	
Topeka, KS	
Jefferson City, MO	
Springfield, IL	
Columbus, OH	
Charleston, SC	
Richmond, VA	
Philadelphia, PA	
Brooklyn, NY	
Boston, MA	

Questions to Consider:

What patterns did you notice?

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Find four cities with the same or nearly the same declination.

_________________________ _____________________________

_________________________ _____________________________

Is there a difference in between the east and west coast of the USA in regards to declination? What difference did you notice?

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The NOAA declination calculator also notes how much the declination is changing in a location over a years time. Look up Anchorage, AK and Albany, NY. Now predict how much declination change Honolulu, HI might experience.

Declination

Latitude:	40° 2' 40" N
Longitude:	105° 13' 9" W
Date	**Declination (+ E | - W)**
2012-11-28	8° 52' 52" changing by -8.0' per year

Anchorage, AK ____________ Albany NY _________________
Honolulu, HI (prediction) _____________ Honolulu, HI (actual) _____________

Pick three cities to explore further that might have an intersting declination pattern.

___________________ ___________________ ___________________
City 1 City 2 City 3

What pattern did you think you might find and what pattern did you actually find?

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This handout will help you discover the relationship of Earth's magnetic field and airport runways. You will use the online magnetic declination calculator provided by the National Geophysical Data Center in Boulder, CO. and Google Maps to check airport runway designations. Maybe you will find a runway that has not been updated yet!

Introduction: How do USA airports designate their runway numbers?

Runway Designators. Runway numbers and letters are determined from the approach direction. The runway number is the whole number nearest to one-tenth of the magnetic azimuth of the centerline of the runway, measured clockwise from the magnetic north. The letters, differentiate between left (L), right (R), for parallel runways.

Travelers have struggled with the complexity of navigating by compass for centuries, and modern American travelers are no exception. The magnetic poles don't line up with the geographic ones, and the difference between them is an angle called declination. As if this wasn't enough of a nuisance for navigators, the Earth's magnetic field drifts, causing the angle of declination to change over time.

So the drifting magnetic north means that airport runways, periodically, need to be renamed.

Your Task:
Read the following article about the Tampa international airport's runway designation change. This is the first time the designations have changed since the current Tampa International Airport opened in 1971.

The shifting of the planet's northern magnetic pole forced Tampa International Airport to readjust their runways on Thursday, according to a report by Jeremy A. Kaplan of Foxnews.com.

Kaplan reports that the shifting of the Earth's magnetic fields, spurred by the drifting of the North Pole towards Russia, has prompted officials at the Florida airport to shut down their primary runway until January 13. The temporary closure will give them time to change their taxiway signs to account for the magnetic changes, Federal Aviation Administration (FAA) officials told Fox News.

"The poles are generated by movements within the Earth's inner and outer cores, though the exact process isn't exactly understood. They're also constantly in flux, moving a few degrees every year, but the changes are almost never of such a magnitude that runways require adjusting," Kaplan reported, citing FAA spokesman Paul Takemoto as a source.

The runway's listing on aviation charts will be changed from 18R/36L (representing 180-degree approach from the north and the 360-degree approach from the south) to 19R/1L, according to various media sources.

When Kaplan asked Takemoto how often these kinds of adjustments were needed at airports, the FAA spokesman told him, "It happens so infrequently that they wouldn't venture a guess"¦ In fact, you're the first journalist to ever ask me about it." He was also quick to point out that passenger safety will not be an issue, but that the changes were needed "to make sure the precision is there that we need."

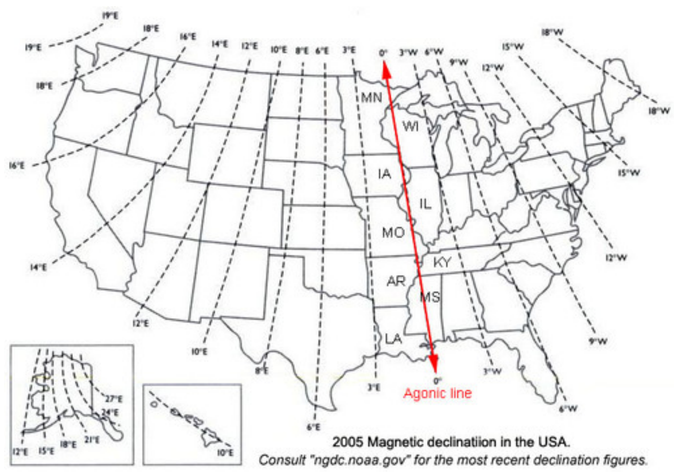
According to a Wednesday article in the Tampa Tribune, late this month, the airport's east parallel runway and a seldom used east-west runway will also be closed so that officials can change signage to reflect their new designations as well.

"The Federal Aviation Administration required the runway designation change to account for what a National Geographic News report described as a gradual shift of the Earth's magnetic pole at nearly 40 miles a year toward Russia because of magnetic changes in the core of the planet," the Florida newspaper's website also said.

Source:
http://www.redorbit.com/news/oddities/1975752/magnetic_pole_shift_forces_runway_closure_at_florida_airport/

Activity Process:
This is a great magnetic declination activity that has real world application that few people know about. As you discovered from the article you read, runway designations change over time because the magnetic poles slowly drift on the Earth's surface and the magnetic bearing will change. Depending on the airport location and how much drift takes place, it may be necessary over time to change the runway designation. As runways are designated with headings rounded to the nearest 10 degrees, this will affect some runways more than others. As you explore different airports runway designations, you might actually find a few airports that have not relabeled their runways yet!

Here are a few questions to consider before you begin. This is a magnetic declination map for reference.



2005 Magnetic declinatiion in the USA.
Consult "ngdc.noaa.gov" for the most recent declination figures.

1. Do you think that airports in one geographical location of the Unites States would be more affected by magnetic poles drift than another?

2. List a few states that you think might be impacted more and why.

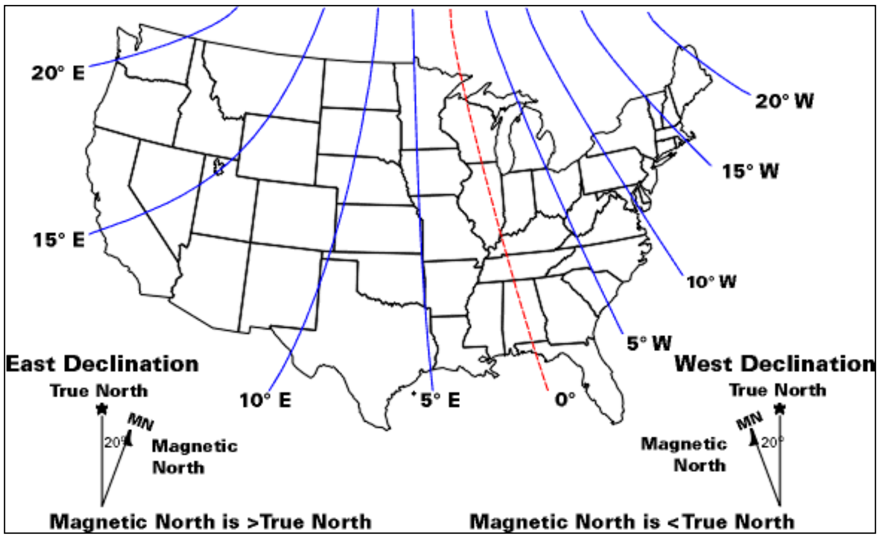
Compare the two declination maps from 1995 and 2005.
Note three differences.

1. ____

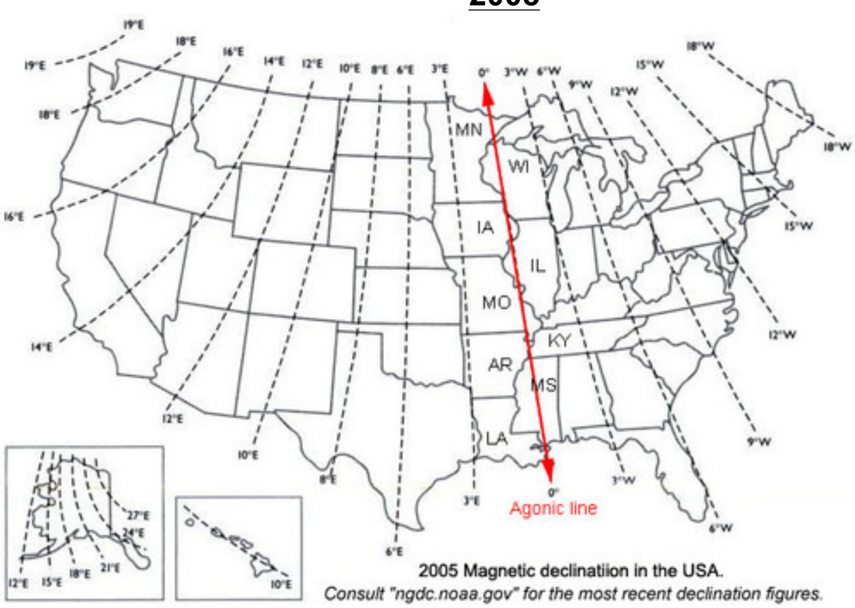
2. ____

3. ____

1995



2005



2005 Magnetic declinatiion in the USA.
Consult "ngdc.noaa.gov" for the most recent declination figures.

Step 2: Now look at the list of airports in your handouts and select five airports to investigate their runway designations. HINT: it will be more interesting if you pick a variety of airports from across the country.

Look at the 2005 Declination map above then based on the airport location, give an estimate what the airport's north /south runway would be numbered.

Airport 1 ______________________________ ____________
(name) (runway)

Airport 2 ______________________________ ____________
(name) (runway)

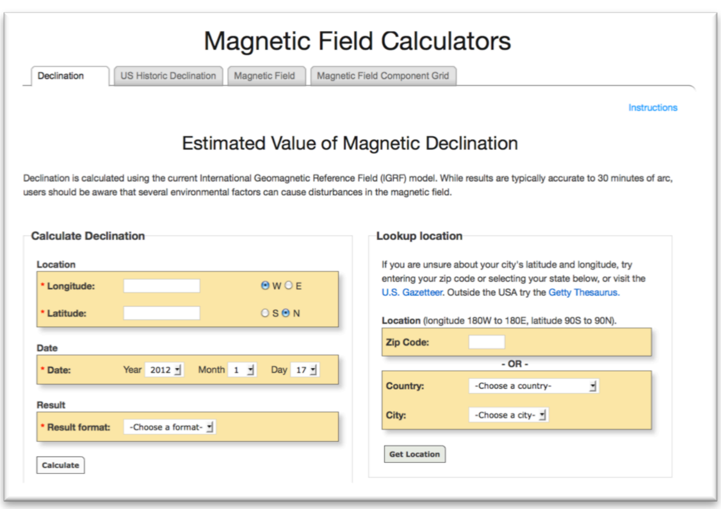
Airport 3 ______________________________ ____________
(name) (runway)

Airport 4 ______________________________ ____________
(name) (runway)

Airport ____________________ __________ ____________
(name) (runway)

Step 3: Airport Runway Record sheet:
Working with your Airport Runway data table on page 54, enter the airports you have chosen into the table.

Next enter the airport's coordinates into the NGDC.
http://www.ngdc.noaa.gov/geomagmodels/struts/calcDeclination



Use the current date and choose "html" for the result format. Then click Calculate.

You will then get a map and declination. Record the declination for your airports in two digits.

Follow the instructions to calculate the runway designation and then use Google maps to look up the airport. If you select satellite view, you will be able to zoom in and check the runway designation to see if the runway is marked correctly.

How to Calculate:
Subtract the magnetic declination from the runway true heading for this airport

____________________ - ____________________ = ______________________ Divide the number by 10.
The rounded value is the actual runway number

EXAMPLE:

Airport	Latitude	Longitude	Declination	Runway 1 True heading	Runway Number	Runway 2 True heading	Runway Number
Example: SFO	37.619 N	122.375 W	14	298	28, 10	27	1, 19

Magnetic declination for the SFO airport on 01-26-2012 = 14° 4' 13"
Runway 1:
Subtract declination from the runway heading:
298 – 14 = 284
Divide the number by 10
= 28.4
The rounded value 28 is the actual runway number
The numbers at the ends of a runway always differ by 18. So the runway numbers for runway 1 are 28 and 10. (28 – 18 = 10)

Extension: Explain how the other end of the runway is labeled and how you might calculate that.

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Checking for Understanding:
Now can you do the math in reverse?
If the Runway for Boulder, Colorado is labeled 8 …. What is its geomagnetic declination?

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Now Let's Investigate Airport Runway Designation!
STEP 1: Estimate the Airport Runway Designation:
Choose three or four airports from the data tables at the end of this activity. Consider choosing a small airport, a large airport and airports that are in different geographical locations across the country.
Using the Magnetic Declination Map below, estimate what a runway designation might be for each airport.

2005 Magnetic declinatiion in the USA.
Consult "ngdc.noaa.gov" for the most recent declination figures.

Airport 1 ____________________ ____________________
(name) (runway)

Airport 2 ____________________ ____________________
(name) (runway)

Airport 3 ____________________ ____________________
(name) (runway)

STEP 2: Now you will learn to calculate the runway designation and determine the runway number.
Look at the example below for the San Francisco Airport (SFO). Follow the instructions step by step.

Airport	Latitude	Longitude	Declination	Runway 1 True heading	Runway Number	Runway 2 True heading	Runway Number
Example: SFO	37.619 N	122.375 W	14	298	28, 10	27	1, 19

How to Calculate:
Subtract the magnetic declination from the runway true heading for this airport

____________________ - ____________________ = ______________________ Divide the number by 10.
The rounded value is the actual runway number

EXAMPLE:
Runway 1: Magnetic declination for the SFO airport on 01-26-2012 = 14° 4' 13"
Subtract declination from the runway heading:
298 – 14 = 284
Divide the number by 10
= 28.4
The rounded value 28 is the actual runway number

Now let's try to determine the runway numbers for Runway 2.

Magnetic declination for the SFO airport on 01-26-2012 = 14° 4' 13"

Runway 2:
27 – 14 = 13
13/10 = 1.3
Hence runway numbers are 1 and 19
Verify: using Google Maps
NOTE: The numbers at the ends of a runway always differ by 18. So the opposite end of runway 27 is runway 9 (27 - 18), and the opposite end of runway 36 is runway 18 (36 - 18).

Airport	Latitude	Longitude	Runway 1 True Heading (In degrees, Geographic)	Runway 2 True Heading (In degrees, Geographic)
Alabama				
Birmingham Airport	33.564 N	86.752 W	55	235
Arkansas				
Clarksville Municipal Airport	35.471 N	93.427 W	95	275
Arizona				
Scottsdale Airport	33.623 N	111.911 W	44	224
California				
San Diego International Airport	32.734 N	117.19 W	106	286
Colorado				
Denver International Airport	39.862 N	104.673 W	180	001
Florida				
Orlando Sanford International Airport	28.777 N	81.236 W	90	270
Illinois				
Chicago O'Hare International Airport	41.982 N	87.907 W	90	270
Iowa				
Des Moines International Airport	41.534 N	93.663 W	54	234
Kansas				
Garden City Regional Airport	37.928 N	100.724 W	180	000
Kentucky				
Addington Field Airport	37.686 N	85.925 W	47	227
Louisiana				
Baton Rouge Metropolitan	30.533 N	91.15 W	43	223
Maine				
Augusta State Airport	44.321 N	69.797 W	153	333
Bangor Intl Airport	44.807 N	68.828 W	134	314

Source: http://www.globalair.com/airport/state.aspx

Airport	Latitude	Longitude	Runway 1 True Heading (In degrees, Geographic)	Runway 2 True Heading (In degrees, Geographic)
Michigan				
Detroit Metropolitan Wayne County Airport	42.212 N	83.353 W	29	209
Capital Region Intl Airport	42.779 N	84.586 W	91	271
Mississippi				
Cleveland Municipal Airport	33.761 N	90.758 W	178	358
Missouri				
Lambert-St Louis International Airport	38.749 N	90.37 W	122	302
New Jersey				
Atlantic City Intl Airport	39.458 N	74.577 W	118	298
New York				
Greater Rochester International Airport	43.119 N	77.672 W	31	211
North Dakota				
Bismark Municipal Airport	46.773 N	100.746 W	138	318
Ohio				
Findley Airport	41.012 N	83.669 W	180	000
Oregon				
Portland International Airport	45.589 N	122.597 W	119	299
Texas				
Dalhart Municipal Airport	36.022 N	102.547 W	180	360
Virginia				
Richmond Intl Airport	37.505 N	77.32 W	147	327
Wisconsin				
Kings Land O' Lakes Airport	46.154 N	89.212 W	143	323

Source: http://www.globalair.com/airport/state.aspx

This handout will help you learn how to use a compass. There is a lot of information on a compass so we will take it one step at a time.

Using a Compass to Navigate:

The compass consists of a magnetized metal needle that floats on a pivot point. The needle orients to the magnetic field lines of the Earth. The basic orienteering compass is composed of the following parts:

- Base plate
- Straight edge and ruler
- Direction of travel arrow
- Compass housing with 360 degree markings
- North label
- Index line
- Orienting arrow
- Magnetic needle (north end is red)

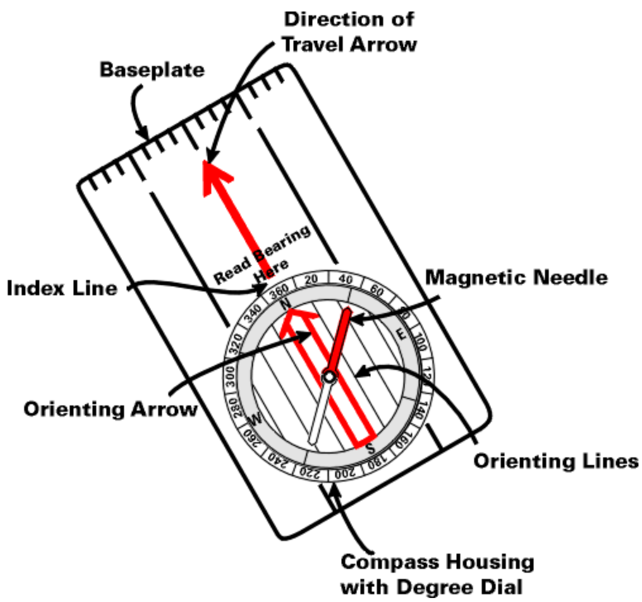


Image source: http://www.princeton.edu/~oa/manual/mapcompass2.shtml

A compass is marked like a protractor, with 360 degrees marked around the edge. A navigation heading is the direction you travel, in degrees measured from the zero mark of due north. The four cardinal directions are as follows:

North= 0 degrees
East=90 degrees
South=180 degrees
West= 270 degrees

When you are following a navigation course, you need to know two things:

What heading on the compass should you follow? This is the direction in which you travel.

How far should you go? This is the distance you should travel.

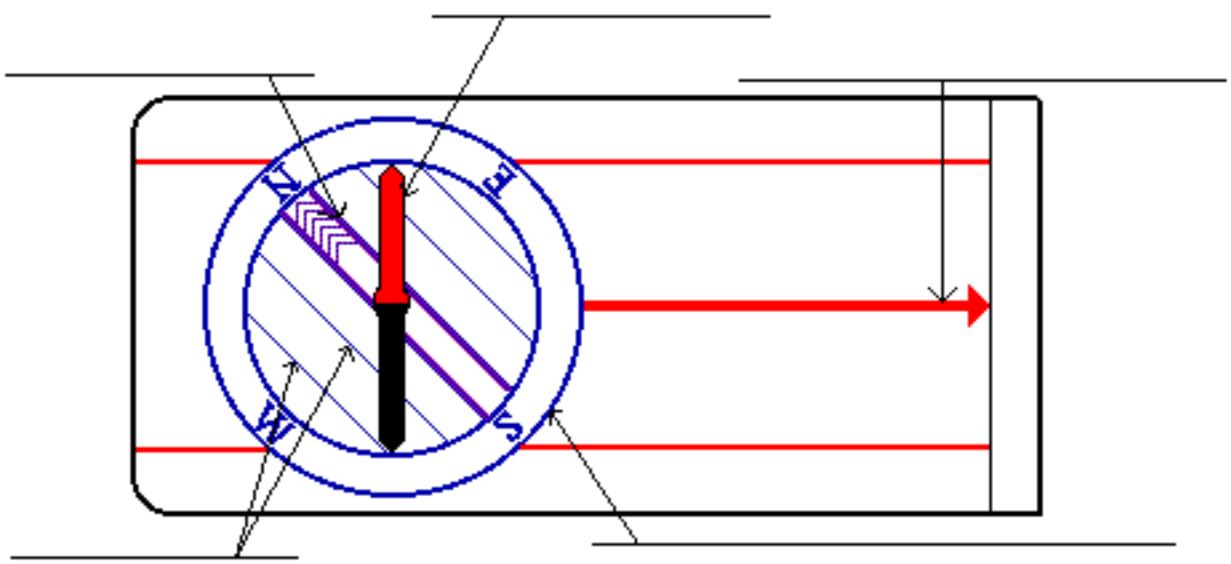
For example, if your directions are to travel 1 mile at 90 degrees, you would be traveling 1 mile due east.

In order to know you are heading in the correct geographic direction, you will need to add or subtract the **magnetic declination** for your location from your desired **geographic heading**.

In the example above, if the declination for your location is 10 degrees east, then you would add 10 degrees to your 90 degree compass heading, giving you a heading of 100 degrees that you would follow in order to be going geographically due east.
From the Compass Dude website—http://www.compassdude.com/compass-reading.shtml

Label the Compass:

Check your self and see if you can remember what you read about parts of a compass. Label the image below.



This handout will help step you through a few activities to learn how to read a compass.

Bearing Compass Use Activity:

No matter the compass, one end of the needle always points north. On our mountaineering compasses, it is *almost always* the **RED** end, but it's a good idea to test your compass before starting to use it. If you are north of the equator, stand facing the sun around lunchtime. Whichever end of the needle points towards the sun is South and the end that points at you is North.

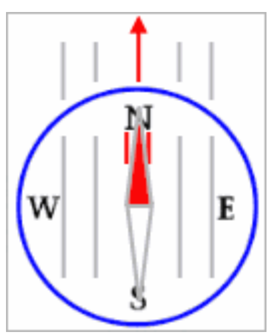
To read your compass,

- Hold your compass steadily in your hand so the baseplate is level and the direction-of-travel arrow is pointing straight away from you.
- Hold it about halfway between your face and waist in a comfortable arm position with your elbow bent and compass held close to your stomach.
- Look down at the compass and see where the needle points.

Compass Reading Tips

- Hold the compass level – if the compass is tilted, the needle will touch the clear lid and not move correctly.
- Read the correct end of the needle.
- Use common sense, such as knowing that if you are heading anywhere towards the sun, there's no way you can be heading north, northwest, or northeast.
- Keep the compass away from metal objects – even a knife, flashlight, or keychain can cause a false reading if too close to the compass.

This compass is pointing due North (also 0 degrees)

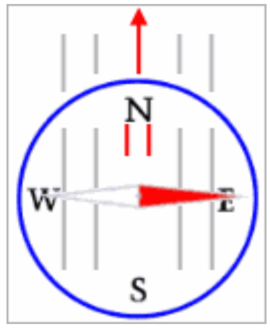


Turn your body while keeping the compass right in front of you.

Notice that as the compass rotates, the needle stays pointing the same direction. [The red end of the needle is always pointing to magnetic north.]

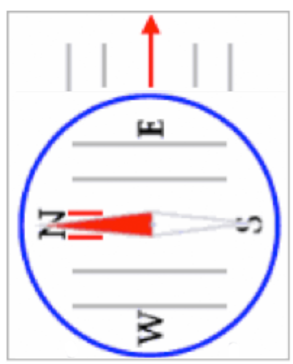
Turn your compass until the red needle points East like the picture below, keeping the direction-of-travel arrow and **N**orth mark facing straight in front of you.

What direction is this compass pointing? ___________________________



- **Important**: The compass needle is pointing towards **E**ast so I must be pointing East, right? No, no, no! This is a very common mistake!
  To find my direction, I must turn the compass dial until the **N**orth mark and the "Orienting Arrow" are lined up with the North end of the needle. Then I can read the heading that is at the Index Pointer spot (the butt of the direction-of-travel arrow).

This compass is pointing East (90 degrees)



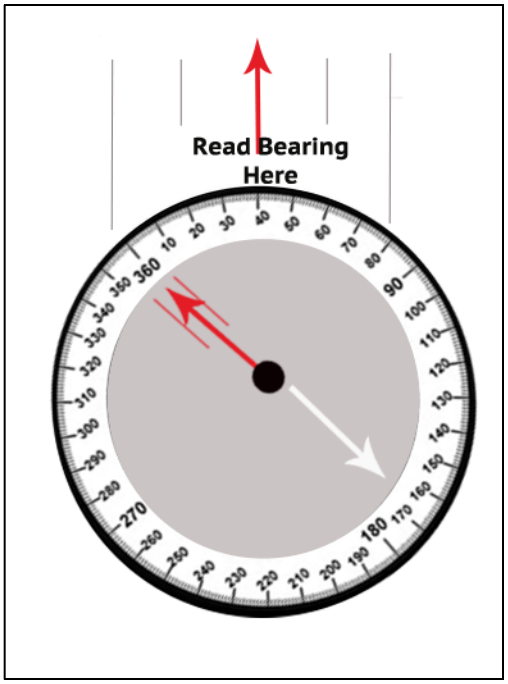
Since the Orienting Arrow is usually two parallel lines on the floor of the compass housing, a good thing to memorize is:

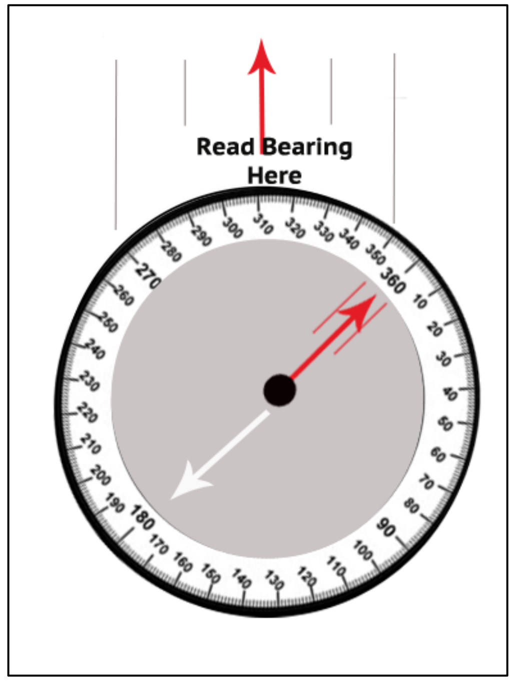
RED IN THE SHED

(Note: Red in the Shed means that the red end of the needle is inside the two red lines marking North on the compass.)

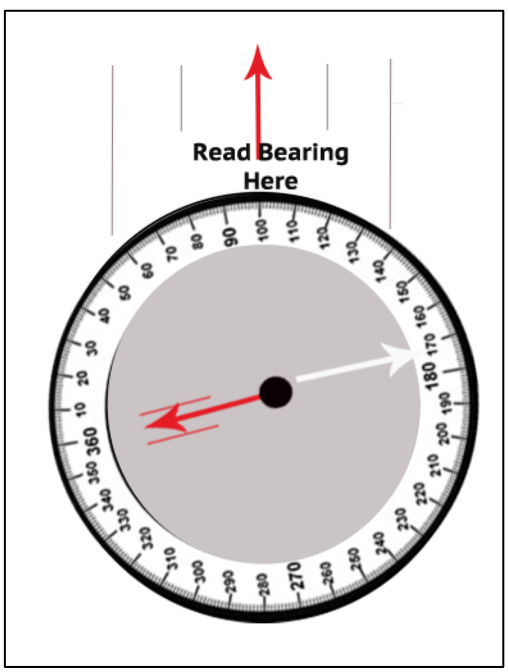
Record the compass bearings:

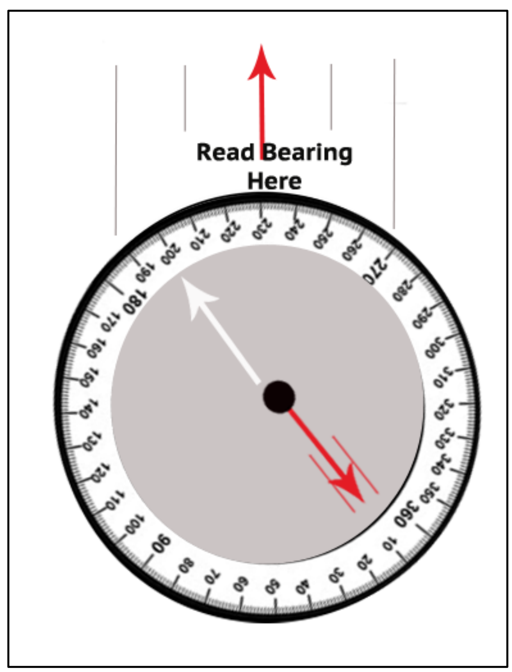
Write the degree and the cardinal direction of each compass below.





_______________ _______________ _______________ _______________



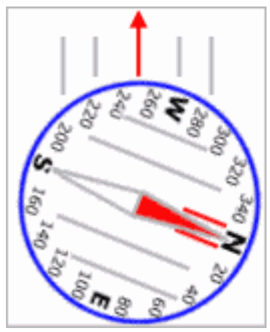


_______________ _______________ _______________ _______________

This handout will help step you through a creating special treasure trove or cache.

Creating a Navigation Map to a Cache Activity:

By simply moving your compass with your body and using the N-E-S-W markings, you can get a good idea which way you are going. This is often all you need from your compass. But, you've probably noticed on your compass, there are also numbers and tiny lines. These represent the 360 degrees in a circle that surrounds you no matter where you are.



When you need to find your way from one particular place to another, you need to use these numbers to find out the **bearing** to that remote place. The direction you are going is called your **heading**. ... [Heading indicates the direction you are pointed towards when moving; bearing is the angle in degrees (clockwise) between your heading and a destination or point of reference.] The image above is a heading of about 250 degrees.

Using your compass, take a few bearings in the room you are in. Move your body until the direction-of-travel arrow points at the following items and then turn the dial until "RED is in the Shed." Read the bearing at the Index Pointer and record what in your room is in that direction.

- 0 degrees = ________________________________
- 90 degrees = ________________________________
- 270 degrees = ________________________________

Geocaching Process:

1) You will have two containers a home base container and a cache container. Decide what you will leave in your cache container!

2) Select one person as the distance-measurer. Measure their stride with a tape measure. Use this to calculate the distance in feet of each heading along the route you plan. For example if Person A has a stride of 2 feet and the cache is 40 strides away, then the distance for the team to travel along that heading is 80 feet.

3) Work out a course heading to where you will hide your cache and the distance required. Write this on a piece of paper and put in the home base plastic container.

4) Using the bearing compass and your distance strider, pace out the position of the cache.

5) Place the goodie items in the plastic container at the destination cache.

6) Be sure to have a couple of people from your team test the heading and distance.

7) Teams will begin with the other team's initial home base and follow to the cache using their bearing compass and their distance strider.

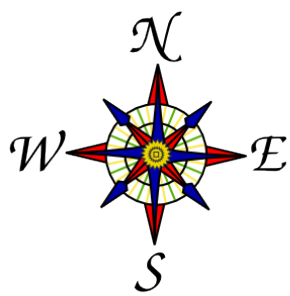
NOTE: If your location is hilly, this will affect your pacing measurements so make a note of it in your directions or calculate for it. Flat landscapes will work best.

Place this sheet in the home base container so another team may follow your navigation instructions.

The directions to the cache are:

Heading: ____

Distance: ____



TEAM MEMBERS:

____

____

____

This handout combines working with declination and navigation. Have fun finding a buried treasure!

The United States is home to a wealth of treasure hunting possibilities. From gemstones and meteors, to old civil war coins and pirate treasure, modern day treasure hunters sometime stumble upon old clues like this old note from 1823. What clues can you gather from this text?

We will need to step through the following process to solve this mystery and find the treasure.

A) First, do we have a location to start looking? Use the internet to see if you can find a USA location to begin our search. ________________________________

B) Are there further clues to narrow down the location? (HINT: look for street name words)

____

C) The bearings in this note are from 1823 and are referenced from a compass because it states the bearings in magnetic degrees. What do you know about earth's magnetic field? Will these bearings be the same today as they were in 1823? Explain your answer.

____

____

____

____

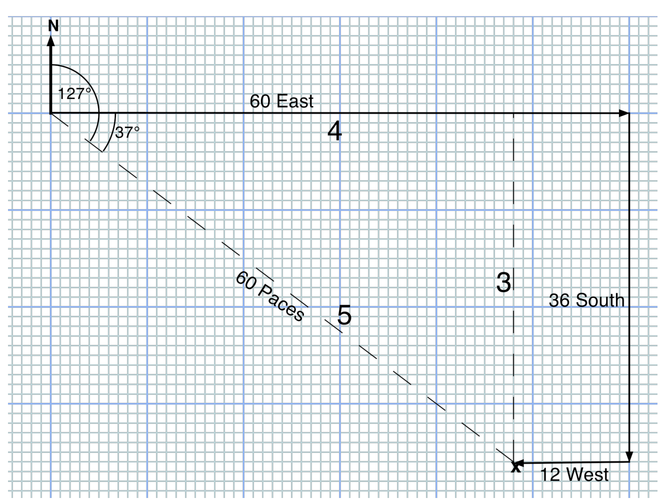
D) We have a very excellent tool to use to check the historic magnetic declination. Go to NOAA's Historic Declination Calulator. http://www.ngdc.noaa.gov/geomag-web/#ushistoric

(SPOILER ALERT) The latitude and longitude coordinates you should use should be for Long Beach, CA; the eastern most intersection of East Shoreline Drive: 33.764626° N, 118.183765°W.

You must get the declination for both 1823 and today, 2013.

1823: ____________________ 2013: ________________________

E) Now we need to shift gears a bit. Use the graph paper provided to draw out the directions in the note. 60 paces E, 36 paces S, 12 paces W



To solve this mystery we will need to use some geometry. Look at the paces you have just drawn. Using a ruler close the shape by connecting the start and the end.

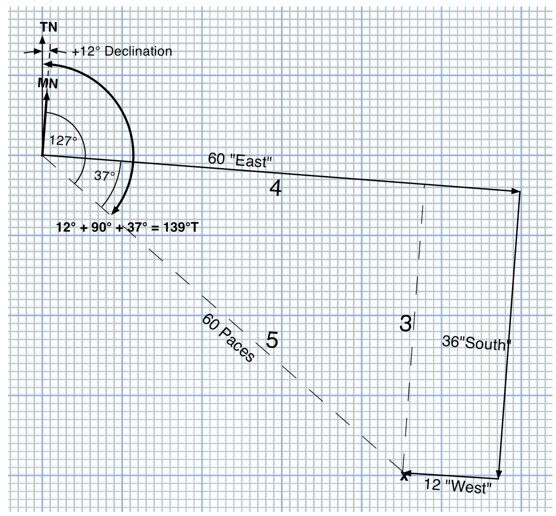
Notice the two shapes within the total shape.

F) Draw a line at the start to designate True North and label it. Next find the angle of the start with your protractor. Now go back to the note. The direction from the start is East (090°). Locate the right angle create by True north and the starting pace line. To find the bearing of the treasure we will add 90° + 37°. The bearing is ________ East of North.

G) Will the shape the pirate paced out change or be the same from 1823 to 2013?

____

F) Using the information from the US Historic Declination calulator we know the declination in **1823** was **+12.18333°**, that is, magnetic north was some 12° east of True or Geographic North. In **2013**, the declination for the same position is **+12.40000°**. So the change in direction of the magnetic field in Long Beach, California has been relatively small, less than 1 degree.



Since Magnetic north is east of True north, the magnetic bearing of 127° in 1823 was actually a true bearing of (127 + 12.18333°) or 139.183°.

Correcting for the change of declination, today's magnetic bearing would then be the True bearing *minus* today's declination (since magnetic north is east of true north), a magnetic bearing is _______.

____________________	-	____________________	=	____________________
True bearing		today's declination		magnetic bearing

SOLVE PART 1: LONG BEACH CALIFORNIA TREASURE HUNT

a) Where is the treasure with respect to the starting point in terms of geographic direction and distance?

b) If you use a compass today, where is the treasure with respect to the staring point in terms of magnetic direction and distance?

But wait! There's more! There is also a Long Beach, New York, and a Shore Road, whose easternmost intersection, with Pacific Boulevard is at 40.584103°N, 73.640915°W. You can check Google Maps again. So now repeat the exercise for this location, again getting the position relative to the starting point in terms of distance along with geographic direction and magnetic direction.

SOLVE PART 2: LONG BEACH NEW YORK TREASURE HUNT

A) The geometry of the puzzle stays the same. Since the location changed we must find the new declinations.Go to NOAA's Historic Declination Calulator. http://www.ngdc.noaa.gov/geomag-web/#ushistoric

The latitude and longitude coordinates you should use should be for Long Beach, New York, and a Shore Road, whose easternmost intersection, with Pacific Boulevard is at 40.584103°N, 73.640915°W

You must get the declination for both 1823 and today, 2013.

1823: ______________________ 2013: _____________________________

Use the Graph paper provided to draw out the treasure map and then adjust for the difference in declination

a) Where is the treasure with respect to the starting point in terms of geographic direction and distance?

b) If you use a compass today, where is the treasure with respect to the staring point in terms of magnetic direction and distance

You will learn about the Sun's connection to aurora and Earth's magnetic field. Read about the legends of aurora and create a legend of your own.

Legends of the Aurora

Excerpted from http://www.gi.alaska.edu/asahi/hist01.htm

Every Northern culture has oral legends about the aurora, passed down for generations. The Eskimos, Athabaskan Indians, Lapps, Greenlanders, and Northwest Indian tribes were familiar with this mysterious light in the sky.

True heavens
Ancient Eskimo stories are often associated with notions of life after death. Some thought that the aurora was a narrow torch lit pathway for departed souls going to heaven. Others thought spirits happily playing soccer with a walrus skull caused the aurora.

Powerful spirit
To some cultures, the aurora was almost a living entity. Waving white handkerchiefs, whistling, or spitting at it would make it change shape. The elders of Barrow, Alaska recall wielding knives to fend off the aurora in case it tried to carry them away. To the Iglulik Eskimo, arsharneq or arshät was a powerful spirit who assisted shamans.

Fearful omens
Where aurora were rare, their appearance portended omens, much like comets or meteor showers did.

People living far from the Arctic can only see the aurora on the rare occasion that it is powerful enough to reach their latitude. In these cases, the lower portion may be obscured by the curve of the earth and only the upper red portion visible. People were often horrified to see the northern sky glow the color of blood, believing it to be a harbinger of disaster or war.

The philosopher Seneca wrote of Romans during a rare, red aurora rushing off to save the port of Ostia thinking the town was ablaze. In 1583, thousands of French villagers made pilgrimages to the church in Paris after seeing "warnings from Heaven" and "fire in the air."

Violent battles
The aurora was also associated with battles; people imagined they saw warriors wielding drawn swords or spears clashing in the sky. The bible contains several accounts of visions that can probably be attributed to the aurora. As late as 1716, tenants of the Earl of Derwentwater saw visions of his execution in a particularly bright, active aurora. Afterward, the aurora was known locally as Lord Derwentwater's Lights.

The King's Mirror
This famous Norwegian work was written in the mid 13th century. A prince interviews his father, the king, on various topics including the source of the northern lights. What makes this particular work interesting is that the aurora is discussed as a natural phenomenon rather than a mystical, supernatural one.

Create your Aurora Legend Outline here. If you prefer you may use the storyboard on the next page. On another piece of paper your might work on your groups illustrations.

Title: ___________________________________

Setting: ____

Introduction:

____

____

____

____

____

Aurora Explained:

____

____

____

____

____

____

____

Conclusion:

____

____

____

____

Aurora Legend Storyboard:

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. You will build a simple magnetometer with your group following the directions below.

Team Members: ________________________ ________________________

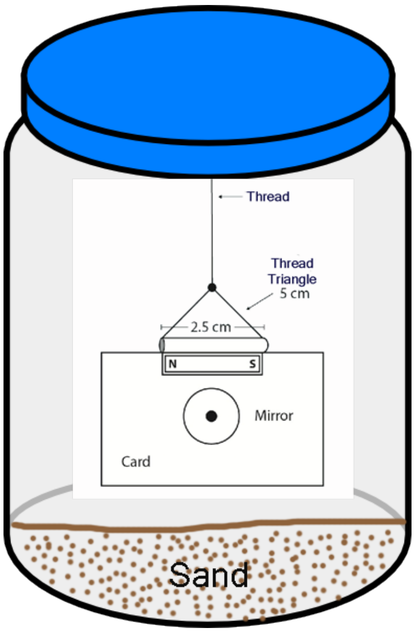
________________________ ________________________

IMPORTANT SAFETY TIP: **DO NOT** point the laser pointer at other students or at your own eyes. Lasers can cause permanent damage to the retina of the eye.

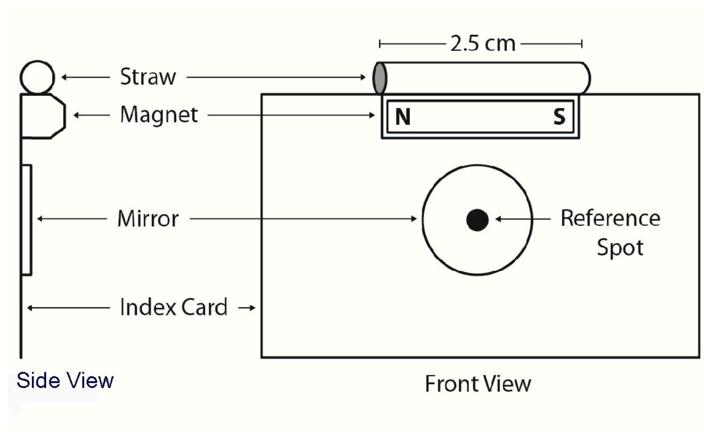
Procedure:

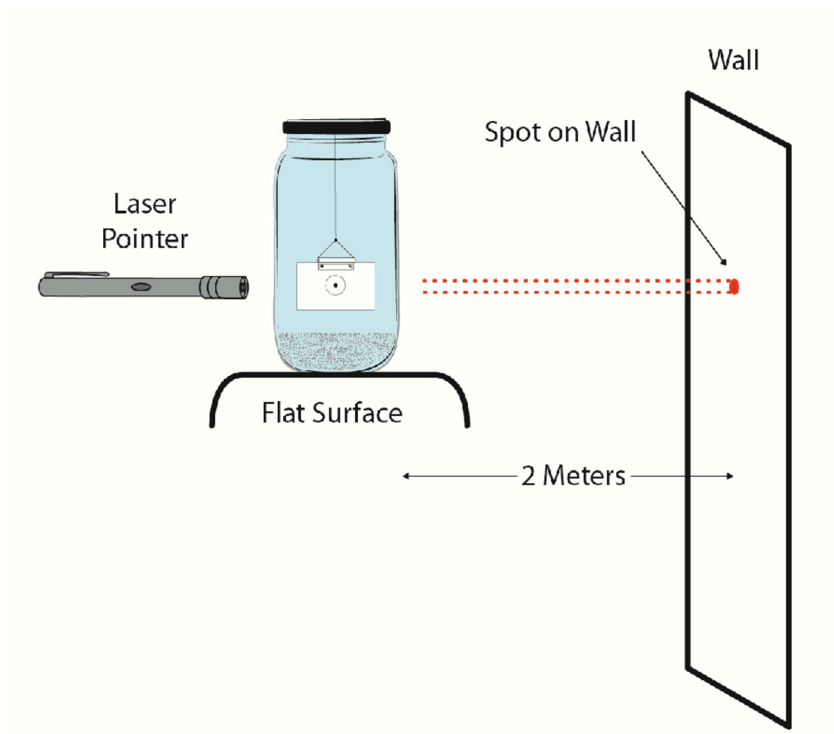
1. Gather your materials:
   a. Quart size jar
   b. Sand
   c. Index card
   d. Scissors
   e. Magnet
   f. Small craft mirror
   g. Straw
   h. Low-melt glue or superglue
   i. Thread
   j. Meter stick
   k. Laser pointer or gooseneck lamp
   l. Nail and hammer
2. Fill the jar with sand to stabilze it according to the diagram below.
3. Use the nail and hammer to put a small hole into the center of the jar top. It should be just large enough to allow you to pass the thread through.
4. Measure and cut the index card so that it will fit inside the jar without touching the sides. Measure the diameter of the jar and subtract 4 centimeters to make sure the card will not touch the sides.
5. With a ruler, draw diagonal lines from corner to corner on the card. The intersection of the lines will mark the center. Glue the craft mirror in the center of the card.
6. Measure and cut a 2.5 centimeter section of a plastic straw and glue the straw to the top of the card and magnet. The top of the card and the magnet should be lined up evenly so that the straw sits on top of the card and magnet. The straw should prevent you from seeing the card or the magnet in its location. The straw is your guide for the string to keep your magnet and mirror in a level position.
7. Run the thread through the straw and tie into a triangle with 5 centimeter sides. Run the other end of the thread through the lid of the jar. Make sure the magnet/card apparatus hangs freely. Tape the thread to the lid.
8. Place the jar on a flat surface and point the laser pointer so that a reflected spot shows on a nearby wall about 2 meters (6 feet) away. Tape a piece of white paper on the wall. Use a pencil to mark the point where the light is reflected. This point will be your reference point.
   NOTE: If you do not have a laser pointer, you can use a gooseneck lamp instead. Make sure to use a clear light bulb.
9. Check your magnetometer to gather data. Measure the changes from the reference spot position to the current position of the reflected light. Record this measurement on your data sheet. This Is the Measured Change In Reflection (due to the reflection of the light). When magnetic storms occur, you will see the reflection point change by several degrees within a few hours, and then return to its normal orientation pointing toward the magnetic north pole. Your magnetometer is sensitive to changes in the magnetic field and the reflected spot will show the changes by slight changes in position. Those changes can be measured using a ruler. Measure the change in reflection in centimeters. Convert the measurement to Degrees of Deflection By multiplying the change in reflection by 0.25 degrees.

Magnetometer:



Card detail:





Magnetometer Data Collection:

Part 1.
Complete the table below with the data your group gathers. Take 15 different measurements. It is ideal to take 2-3 measurements each day over 5-7 days or longer. Measure the distance from the reference point to the reflection mark in centimeters. Convert into degrees of deflection for a 1-meter distance by multiplying by 0.25 degrees for each centimeter of displacement. The measured change in reflection is evidence of magnetic field changes.

Data Collection	Date	Time	Distance (in cm)	Degrees of Deflection	Measured change in Reflection
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					

Magnetometer Data Collection:

Part 2.
Plot the data from Part 1 on the graph below. Determine the scale needed for the measurement data. Label the x axis with the reading number and the y axis with the measurement using either the Measured Change in Reflection or the Degrees of Deflection. Plot the points of the data and then connect the points to create a line plot.

Data Table

How far south can the aurora be seen? In this activity, you will map out aurora sightings to answer this question.

A report on the July/1991 aurora by Lee Siegel
http://www.space.com/scienceastronomy/solarsystem/solar_storm_aftermath_000716.html

In July 1991 Earth was blasted by one of the most extreme magnetic storms of that 11-year solar cycle. The storms caused problems for satellites, triggered voltage fluctuations in some electric power systems, blacked out radio communications for commercial fishing boats and made the northern lights visible at mid latitudes.

Both storms resulted from a major solar flare that erupted Friday July 14 from an active sunspot region. Within 20 minutes, the flare started blasting space around Earth with an intense barrage of protons known as a solar radiation storm. The flare also triggered a mass ejection of electrified gas from the sun's outer atmosphere, hurling the material toward Earth. It hit at 10:40 a.m. Eastern Daylight Time (14:40 GMT) Saturday, triggering a geomagnetic storm that reached category G5, or extreme levels, over high and mid latitudes later in the day.

During the storms, solar wind speeds at times reached 620 miles (1,000 kilometers) per second, which is equal to 2.24 million m.p.h. (3.6 million kilometers per hour) -- roughly twice the normal speed of the solar wind.

****

Step 1

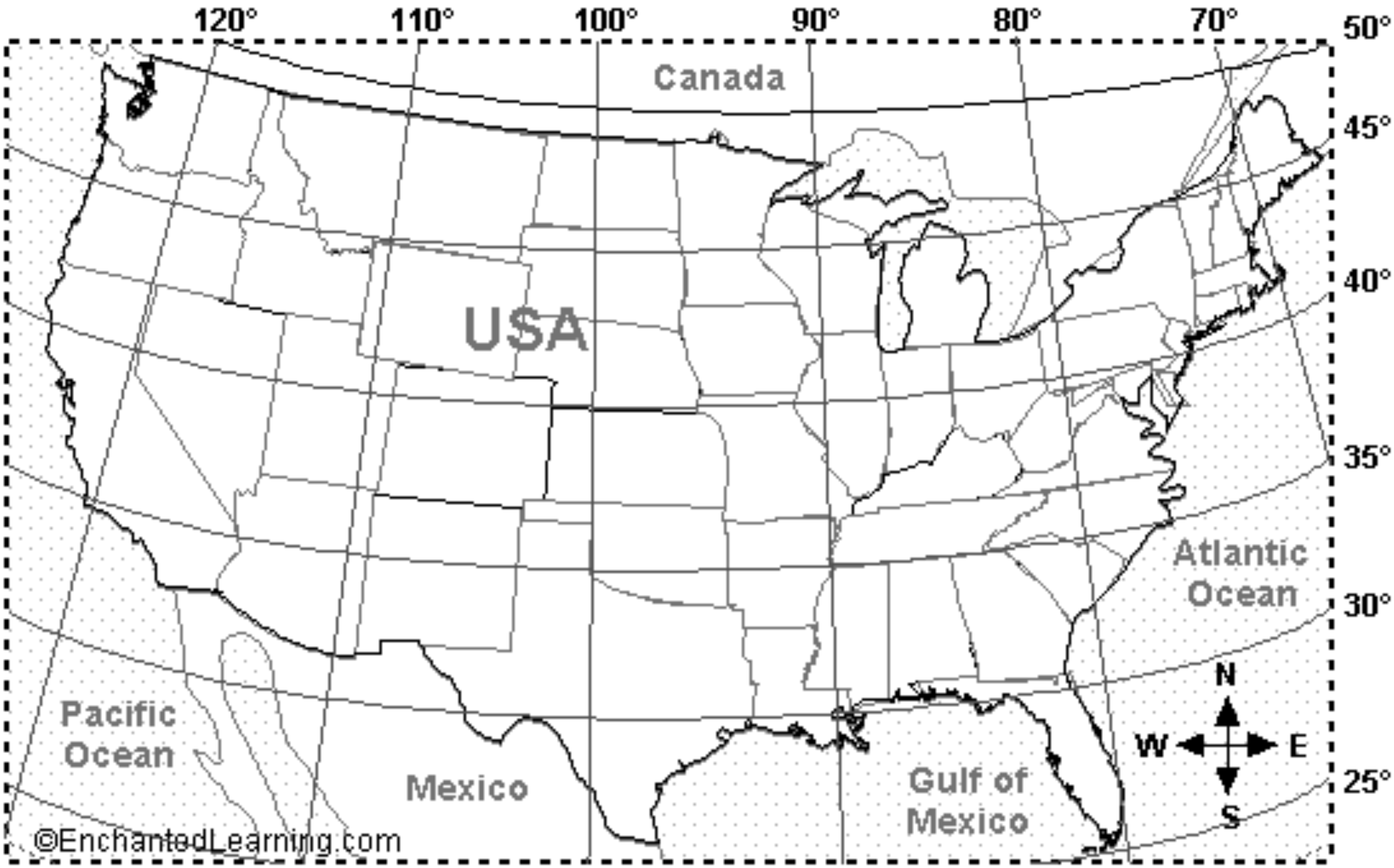
Each city in the following table is a location where the aurora was viewed. Notice the city name is followed by its latitude and longitude. Use the latitude and longitude values to mark a small "x" on the additional map handout where each sighting was recorded on the map of the continental United States (Activity 2.2).

City	State	Latitude	N/S	Longitude	E/W
Harrison	AR	36.2	N	93.1	W
Anza	CA	33.1	N	116.3	W
Wrightwood	CA	34.3	N	117.6	W
Champaign	IL	40.1	N	88.2	W
Rio Rancho	NM	35.2	N	106.6	W
Las Vegas	NV	36.2	N	115.2	W
Pittsburgh	PA	40.4	N	79.9	W
El Paso	TX	31.9	N	106.5	W
Lubbock	TX	33.5	N	101.8	W
Seminole	TX	32.7	N	102.6	W
Fillmore	UT	38.9	N	112.3	W

Do you think this aurora was seen in Denver? ______________________________

Why or why not? ______________________________

Where was the farthest south sighting? ______________________________


120°
110°
100°
90°
80°
70°
50°
45°
40°
35°
30°
25°
Canada
USA
Atlantic Ocean
Pacific Ocean
Mexico
Gulf of Mexico
N
W
E
S
©EnchantedLearning.com

Step 2)

The following image was created with Google Earth using NOAA map data for potential aurora viewing areas. The yellow areas near the pole are the most likely areas for viewing aurora. The light blue shaded areas are less likely.

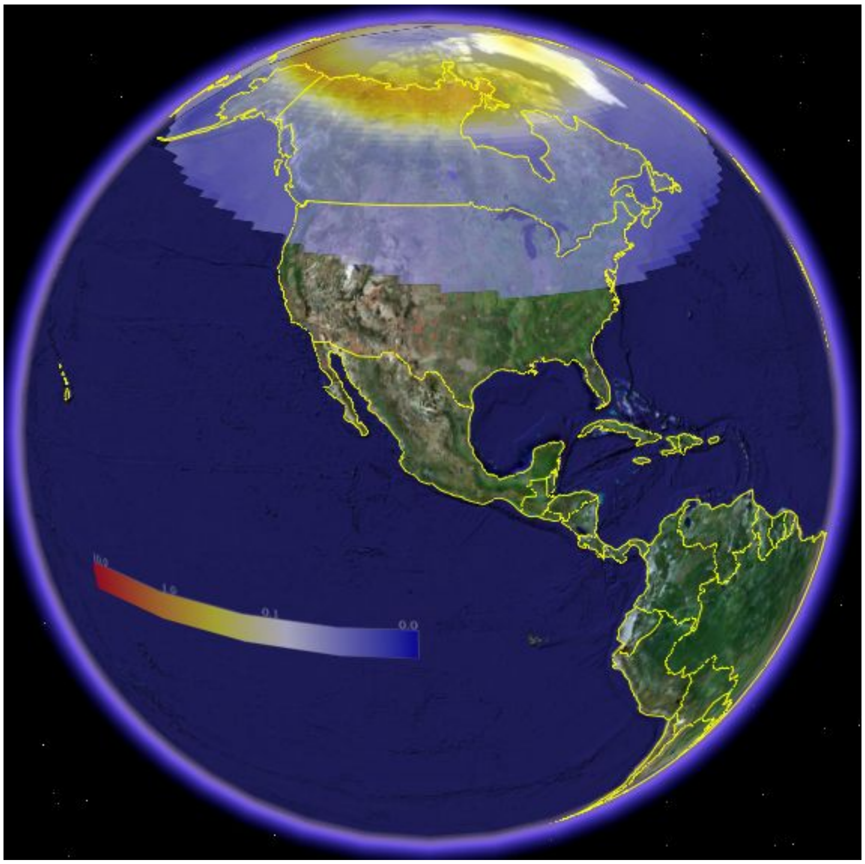


Image source: Google Earth

Comparing your map to the above image, what conclusions could you make about the aurora of July 1991?

Space Weather Prediction Center Activity:

SWPC's Space Weather Operations branch (SWO) is the national and world warning center for disturbances that can affect people and equipment working in the space environment. Jointly operated by NOAA and the U.S. Air Force, SWO provides forecasts and warnings of solar and geomagnetic activity to users in government, industry, and the private sector. SWO continuously monitors, analyzes, and forecasts the environment between the Sun and Earth. The Center receives solar and geophysical data in real time from a large number of ground-based observatories and satellite sensors around the world. SWO forecasters use these data to predict solar and geomagnetic activity and issue worldwide alerts of extreme events.

What is today's space weather forecast?

Go to http://www.swpc.noaa.gov/ and answer the following questions:

Using the Satellite Displays/POES Auroral Maps

- What level is the aurora activity? ____________________
- Is this high, medium, or low activity? ____________________
- Looking at the Northern Hemisphere Movie, describe the farthest south the polar oval extends during the covered period.

  ____

Using Popular Pages/Today's Space Weather

- What is the level of geomagnetic storms? ____________________

Using Popular Pages/3-day Report & Forecast

- What is the solar activity forecast for the next three days?

  ____

Using Popular Pages/Tips on Viewing the Aurora

- What Kp Index is needed to see the aurora at midnight in Denver?

  ____
- What NOAA POES Auroral Activity Level is needed to see the aurora at midnight in Denver?

  ____
- Why might YOU might be interested in using information from this website in your daily life?

Session Four: Field Trip to NOAA's David Skaggs Research Center

This field trip will be a guided tour of the Space Weather Predictions Center, where you will see live real-time data of the geomagnetic field.

The Science on a Sphere (SOS) exhibit facility which can project the Earth's geomagnetic field on a suspended sphere as well as showing solar activity and satellite views of Earth is also another wonderful feature of this field trip.

Write down any questions you may have before you go on your field trip:

Use this field trip guide to record the information you learn about on your visit to NOAA's David Skaggs Research Center.

NOAA – What is going on here?

What does NOAA stand for?

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Why is it important to study space weather?

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What kind of commercial airline flights are the most dependent on the Space Weather Prediction Center and why?

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How many hours a day does the Space Weather Prediction Center stay open to provide data?

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What was the most interesting thing you saw at Science on a Sphere?

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GLOSSARY

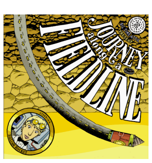
Term	Definition

agonic line	An imaginary line on the earth's surface connecting points where the magnetic declination is zero.
aurora	A faint visual phenomenon associated with geomagnetic activity that is visible mainly in the high- latitude night sky.
azimuth	The direction of a celestial object from the observer, expressed as the angular distance from the north or south point of the horizon to a point. The horizontal angle or direction of a compass bearing.
cardinal directions	**t**he four *cardinal directions* or *cardinal points* are the directions of north, east, south, and west, commonly denoted by their initials: N, E, S, W.
compass	a small magnet suspended so that it can freely point to earth's magnetic north pole
compass bearing	a hand *bearing compass* is used to measure the magnetic direction of sighted objects relative to the user
geocaching	an outdoor sporting activity in which the participants use a Global Positioning System (GPS) receiver or other navigational techniques to hide and seek containers, called "geocaches" or "caches", anywhere in the world.
geomagnetism	The study of the earth's magnetism.
magnetic declination	The angle between magnetic north and true north at a particular location. Also called *magnetic variation*.
magnetic field	area around and affected by a magnet or charged particle.
magnetic storm	interaction between the Earth's atmosphere and charged particles from solar wind.
magnetometer	scientific instrument used to measure the presence, strength, and direction of Earth's magnetic field.
magnetosphere	teardrop-shaped area, with the flat area facing the sun, around the Earth controlled by the Earth's magnetic field.
solar flare	explosion in the sun's atmosphere, which releases a burst of energy and charged particles into the solar system.
solar wind	flow of charged particles, mainly protons and electrons, from the sun to the edge of the solar system.
space weather	changes in the environment outside the Earth's atmosphere, usually influenced by the sun.

RESOURCES

You can explore the concepts and ideas in the GeoMag kit further with these great Apps!

Apps	Information
3D Sun	A major solar flare erupts on the sun. Before long, your phone chirps in your pocket to let you know! Pulling out your phone, you see a 3D view of the sun — a digital reconstruction of satellite images freshly downloaded from NASA's "STEREO" satellites, orbiting millions of miles away.
Aurora Forecast	Aurora Forecast application lets you easily plan to see the Northern Lights. If you are a serious aurora watcher, plan to spend the night with Aurora Forecast application. It's time to see the Northern Lights. Recent auroral activity and forecast data is provided by NOAA POES and Geophysical Institute at UAF.
Geo Bucket	Do you like geocaching? Want an iPad, iPhone, iPod geocaching application that can be used offline for paperless geocaching? Geo Bucket is just the thing for you.
Geocaching Intro	Geocaching is a global treasure hunting game where participants locate hidden physical containers, called geocaches, outdoors and then share their experience online. Find out more about geocaching at Geocaching.com.
Geocaching Toolkit iGCT	Geocaching is a worldwide game of hiding and seeking treasure. A multi-cache involves two or more locations. Sometimes the calculations are easy, but this toolkit can help when calculations become tedious while out there in the field.
SDO	SDO App brings you real-time images from The Solar Dynamics Observatory. SDO is the first mission to be launched for NASA's Living With a Star (LWS) Program, a program designed to understand the causes of solar variability and its impacts on Earth. SDO is designed to help us understand the Sun's influence on Earth and Near-Earth space by studying the solar atmosphere on small scales of space and time and in many wavelengths simultaneously.



USGS Comic: Journey along a Fieldline
http://geomag.usgs.gov/publications/comicbook/GeomagComic.pdf

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