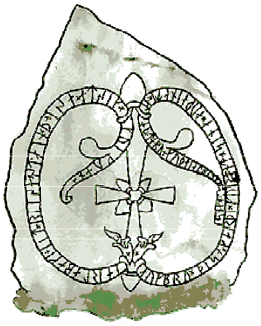
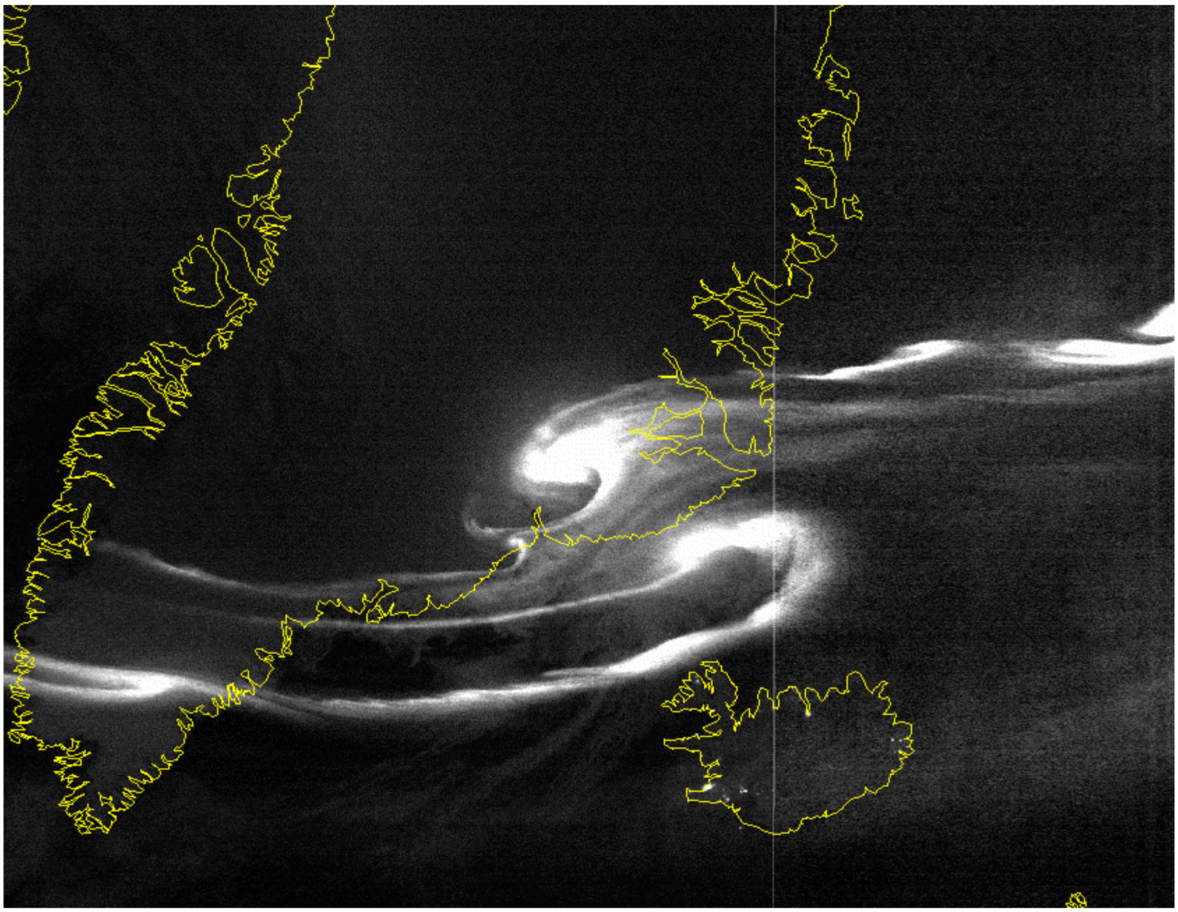
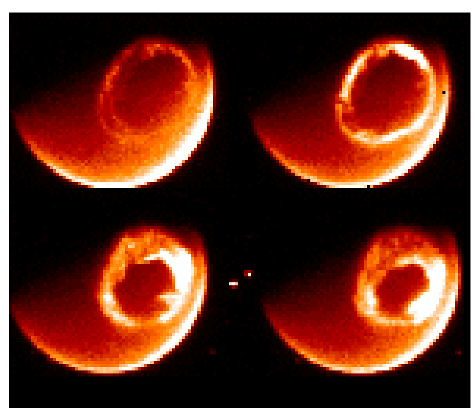


The Northern Lights





A Grade 7-8 guide to understanding the Aurora Borealis through math, geometry and reading activities.

This series of activities will help students understand how the Northern Lights work, what causes them, and how to observe them.

Through a series of math and reading activities, students will learn:

- How aurora are described by scientists and by other students (Reading)
- The geographic locations of aurora based on satellite data (Geography)
- How aurora appear in the sky at different geographic latitudes (Geometry)
- The height of aurora above the ground (Geometry - parallax)
- How to predict when they will appear (Mathematics)
- What Norse Mythology had to say about aurora (symbolic code translation)

This booklet was created by the NASA, IMAGE satellite program's Education and Public Outreach Project.

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For more classroom activities about aurora and space weather, visit the IMAGE website at:

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

The cover shows a view from the NPOESS satellite looking down at an aurora over Greenland. *(http://npoesslib.ipo.noaa.gov/S_sess.htm)*. Viking rune inscription (http://www.commersen.se/vikingar/vardag/runor.html). The three smaller images at the bottom of the page are: (Left) an aurora borealis viewed from the Space Shuttle; (middle) portion of the auroral oval over North America viewed by the DMSP satellite showing city lights; (right) the auroral oval viewed over the Arctic region on July 15, 2000 by the IMAGE satellite.

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Introduction:

Aurora are the beautiful curtains of colored light that are commonly seen in the Arctic and Antarctic regions of Earth, and which have a long history of sightings by humans for over 3000 years. We now know that aurora are caused by high-speed electrons that collide with oxygen and nitrogen atoms in the upper atmosphere. One popular misunderstanding is that these streams of particles come directly from the Sun and flow down into the polar regions along Earth's magnetic field. In this activity, we will read about the scientific explanation for Aurora and also read student essays that describe how aurora make you feel when you see them from the ground!

Objectives:

Students will read essays to be informed about auroral activity and describe the information given.

Materials:

Essays
Student Page

Procedure:

1) Discuss the student's prior knowledge about aurora.

2) Allow sufficient time for the students to read the three essays.

3) Students will answer questions 1 through 5. Encourage the students to refer to the article as needed.

4) Discuss the student responses.

Conclusion:

Students will learn about the aurora phenomenon and how scientists have studied it over the last few centuries. They will learn how older ideas have been replaced by newer explanations.

Nature's Spectacular Light Show

The most spectacular example of the way that the Sun and Earth are invisibly connected is the phenomenon of the Aurora Borealis (Northern Lights) and the Aurora Australis (Southern Lights). For millennia, people have watched them and worried about what ill omens they represented: war, death or the wrath of God. It wasn't until the mid-1800s that scientists finally began to discover many of their mysteries. Like lightning and earthquakes, they were natural events, not supernatural ones. Thanks to intensive study by research satellites during the Space Age, aurora have been substantially de-mystified, even as their ethereal beauty has remained to dazzle us and inspire awe.

Scientists learned that aurora often accompanied magnetic 'storms' and an unsettled magnetosphere; they were produced by flows of charged particles entering the atmosphere; they came and went with the sunspot cycle; and their colors were the product of excited oxygen and nitrogen atoms hundreds of miles above the surface of the Earth.

By the turn of the 20th century, scientists actually created artificial aurora in their laboratories. Once television and the fluorescent lamp were invented, it was pretty clear just how aurora worked. What scientists still didn't understand was what was triggering them. Some thought it was from direct currents of particles from the Sun itself. This is still the explanation you will find in your textbooks today! Other scientists felt it was more complicated than that. Here is what the standard explanation looks like today:

When a major solar storm buffets Earth's magnetic field, it causes some parts of this field to rearrange itself, like rubber bands pulled to their breaking point. This releases energy that causes powerful currents of particles to flow from distant parts of the magnetic field, into the atmosphere. These particles did not originate from the Sun, but were already trapped in the magnetic field like flies in a bottle. Once they reach a charged layer of the atmosphere called the ionosphere, they pick up still more energy like a roller coaster shooting down the other side of a tall hill. The currents of fast-moving charged particles continue to flow along the magnetic field into the polar regions and collide with nitrogen and oxygen atoms in the atmosphere. These collisions produce deep red glows as high up as 1,000 kilometers above the ground, and beautiful curtains of green and blue light at altitudes as low as 90 kilometers. They never reach the ground, though they can sometimes seem as though they do!

(Dr. Sten Odenwald. IMAGE Satellite Program)

Alaskan Student Essays about Aurora

Heavenly Lights ..... *Denali Foldager (Seward Elementary School)*

Beautiful, heavenly lights in the sky, different colors for different dancers way up high. Waves like a colorful mid ocean, swimming around in the sky like a dance that never ends. Shimmering and shiny colors across the world, like a colorful raindrop surrounded by a black puddle. Heavenly lights that are peaceful like a flower, but big and colorful as the sun and lots of rainbows. Its colors glowing into the night like it's the diamond and the stars are the gems. Alaska is as beautiful as the northern lights. You could almost touch them because they seem so close to you when you look up at the sky. It makes me feel happy and proud to live in Alaska. The great, wonderful northern lights will always be there when you need them or when you don't. The colors will brighten up your day some way or another. Even though when you can't see them, you can always feel them around you. A swirl of colors all in one. It's either the colors on a cold night or just when you're seeing them for the first time. But just knowing that you have seen the blue, red, or even green the colors are great. Skies, I think, would never be the same without the colorful, calm dance of the heavenly lights. It would just be black with no rainbow to brighten your day and dancers would have no color to their dances. The colors are magnificent and nothing will change that. Color after color day after day a new color is made into the swirl to make it better. All of the auroras are magnificent and heavenly. It doesn't matter what you call it, heavenly lights, gates to heaven, rainbow in the sky, all of them are the same. Auroras will always be there colors and all.

The Compelling Dance of Light .... *Sonta Hamilton (Mt. Edgecumbe High School)*

What can a person find by looking deep into the Alaskan Aurora Borealis? The Alaskan northern lights are usually a pale hue of green and purple. No matter what the color is at that time, people witnessing the event find something within themselves. Ancestral generations that have resided in Alaska's great outdoors over many years have felt that warmth of life that the northern lights have breathed into them. When the night air is crisp and calm, the onlookers are still comforted and feel enriched with a quiet hope. The beams and flashes of vibrant color in the creamy dark sky spreads like a blanket over the land and its inhabitants. There are many moments of quiet stillness and wonder that spreads throughout the vast snow-powdered land. Changes occur in a swift motion, and a person is strangely hypnotized by the northern light's effective grasp on the earth's skies. Its wispy enchanting hands grab a strong hold and guide a person on a journey that tells a comforting story. There is no need to drink hot coca on this night, for the spectacle warms you inside and out. Take off those worn-out gloves and dance with the sky, just as the soft gentle bounce of a person mask dancing can be kept in sync with the swaying colors as it glides through the night's sky. The momentum and beat speaks the northern lights story. A story told by the northern lights is one that a person's ancestors have heard and witnessed on many blustery nights. The story is whispered in and out of different souls, each with a different meaning. All of the colors and resonant light ignites a spark in the many soul seekers of this event. These are the moments in the wilderness of Alaska that a person can feel fortified with everlasting hope towards a secure future. Events such as these don't last one single night; a person remembers the northern lights throughout their life.

To read more essays by Alaskan students, visit the IMAGE 'Alaskan Schools' web page at:

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

Student Name ______________________________________ Date _____________

Read the accompanying essays about aurora and answer the following questions based on what you have learned in each essay:

1) Why do aurora make some people feel strong emotions?

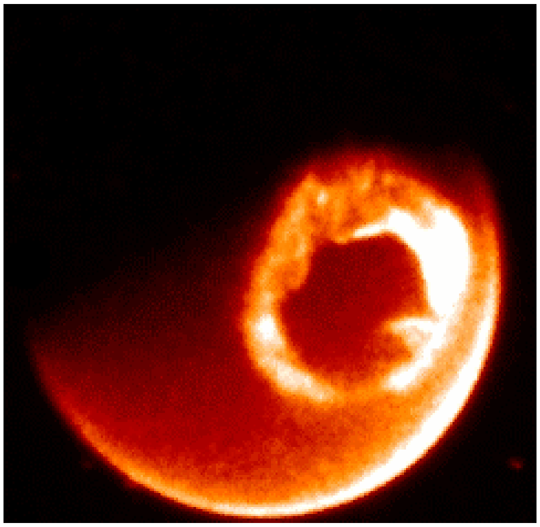
2) What kinds of colors and shapes are seen in an aurora? Be sure to cite specific examples from each essay.

3) Compare the essay by Denali Foldager and Sonta Hamilton. Do you think age makes a difference in the way some people express themselves?

4) According to Dr. Odenwald, what kind of explanation has been given for why aurora occur?

5) Is there a natural phenomenon you have witnessed that made you feel like the Alaskan students did? Describe the circumstances.

Activity 2 Where to See an Aurora



As this image from the IMAGE satellite shows, from space, the aurora look like rings of light surrounding the North and South Poles. This activity has students plot the location and boundaries of a typical auroral 'oval' in the Arctic region. They will see its geographic extent, and determine its relationship to familiar continents and countries. They will also see that it is centered on the North Magnetic Pole and not on the North Geographic Pole. This is a clue that Aurora are related to Earth's magnetic field.

Math and Science Objectives:

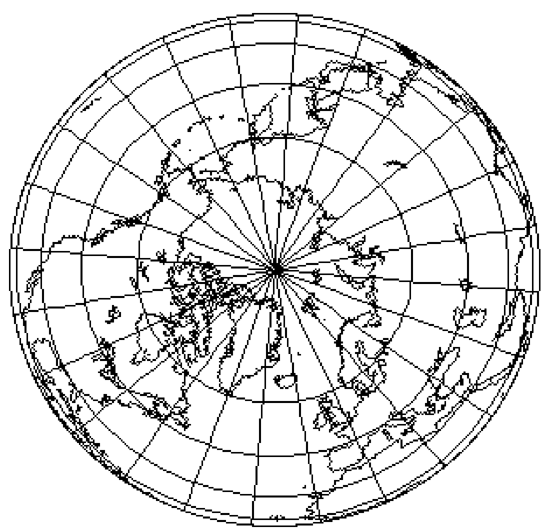
Find and describe locations on maps using geographic coordinates.
Graphs can be used to show a variety of possible relationships.
Graphs can be used to make predictions about the phenomena being graphed

Sample questions:

1...Where would you travel in North America to see aurora? **Answer: To Canada or Alaska**
2...About where is the center of the auroral oval located? **Answer : +78 North 104 West**
3...How far is the center of the auroral oval from the North Pole? **Answer: About 500 km.**
4...What is the range of widths of the auroral oval in kilometers? **Answer: From about 500 to 1500 km.**
5...If you were located at (100, 68) where would you look in the sky for the aurora? **Answer: Straight up!**
6...If you were located at (100,40) where would you see the aurora in the sky? **Answer: Northern horizon.**

Materials:

Ruler / Straight edge
Color pencils
Atlas



Student Name ____ Date _______________

The Northern Lights are seen most dramatically in only certain places in North America.

Step 1) Plot the points in the satellite data table onto the geographic grid.
Step 2) Connect the points in the two rings which define the auroral oval boundaries.
Step 3) Color the resulting enclosed area with your favorite auroral colors!
Step 4) Identify the visible landforms.

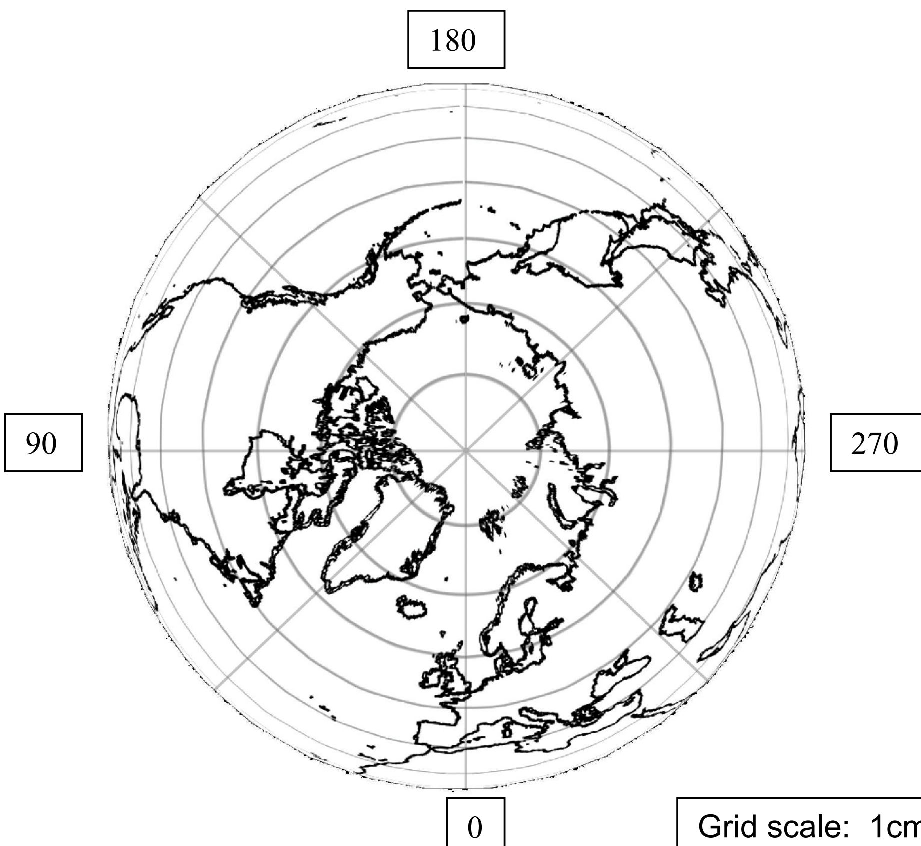
Note: The points are identified as ordered pairs: (Longitude,Latitude)

<u>Outer Ring of Auroral Oval:</u>

1...(270,65)	**2...(225,64)**	**3...(180,60)**	**4...(135,55)**	**5...(90,50)**	**6...(315,63)**
7...(0,60)	**8...(40,63)**	**9...(45,60)**	**10..(60,60)**	**11..(115,50)**	**12..(160,58)**

<u>Inner Ring of Auroral Oval:</u>

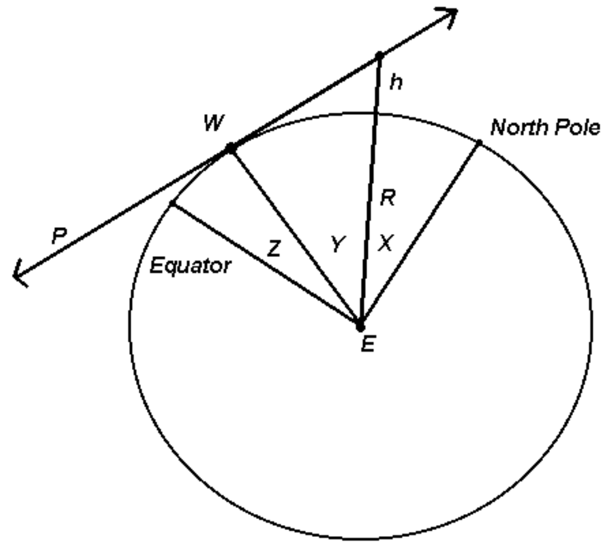
1...(270,78)	**2...(225,72)**	**3...(180,70)**	**4...(135,67)**	**5...(90,65)**	**6...(315,67)**
7...(0,75)	**8...(40,72)**	**9...(45,70)**	**10...(60,67)**	**11...(115,62)**	**12...(160,70)**



Grid scale: 1cm = 1400 km

Activity 3 Aurora Viewing from the Ground

Although the best viewing for the Aurora Borealis is near a latitude of +68°, because these curtains of light extend over 1,000 kilometers above the ground, they can be seen at other latitudes as well.



Key: This is the final construction.

Objectives:

Students will read to perform a task.
Students will construct a drawing to determine the optimum viewing angle of an aurora.

Benchmarks:

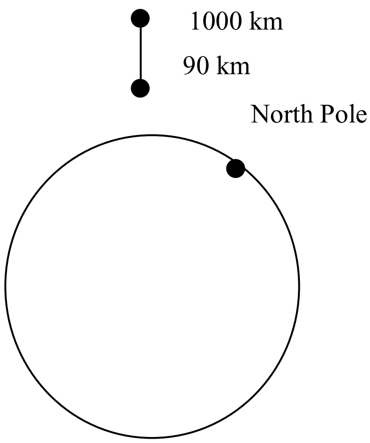
Mathematical ideas can be represented concretely, graphically, and symbolically.
Understand that writing incorporates circle charts, bar graphs, line graphs, tables, diagrams, and symbols.

Teacher Key (sample answers):

1. The directions are used to construct a diagram (shown above) to help students determine an optimal viewing latitude of an aurora.
2. The diagrams allow a visual image of the directions and help to clarify the directions by showing the desired results.
3. The word perpendicular means that the tangent line P meets at a 90 degree angle. This provides a right triangle.
4. The center of the Earth, E, can be located by constructing the perpendicular bisector of any two chords. Another method is to fold the circle creating two diameters and where the two diameters intersect is the center of the circle, or Earth in this case.
5. The top of the aurora is located at R+h = 6378 km + 1000 km = 7378 km
6. Cosine Y = (Earth's radius) divided by the height in number five.
   Make sure that the calculator is in the degree mode. Next, use inverse cosine (6378 divided by 7378). The resulting angle should be 30 degrees, rounded to the nearest degree. This is the measure of angle Y.
   When determining angle Z, use 65 – 30. The measure of angle Z is 35 degrees.

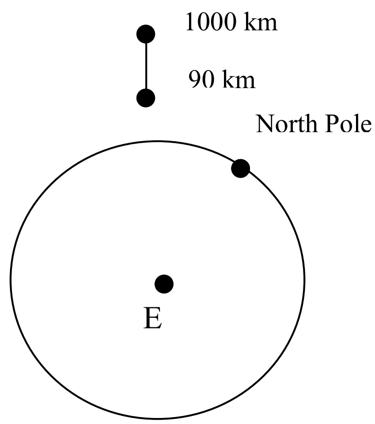
Student Name ____ Date _______________

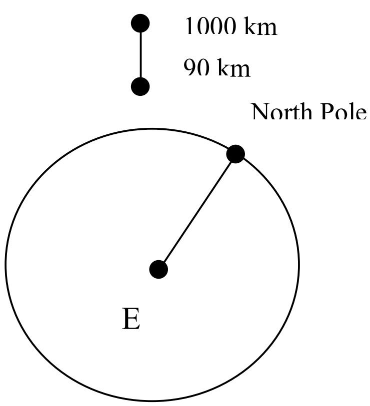
The following steps are used to create a drawing that depicts the optimum viewing angle for an aurora. First, read the steps. Next look at the given diagram and then answer the questions at the end of the reading.



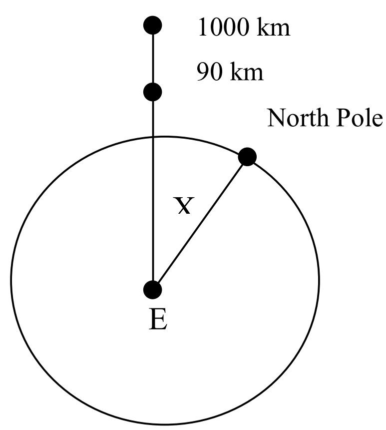
The figure at the left is the Earth . The aurora are 90 to 1000 km above the Earth.

Step 1. Locate the center of the Earth. Label this point E.

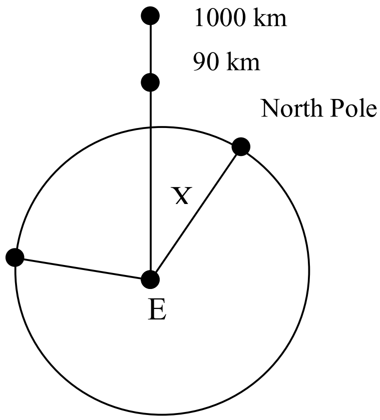




Step 2. Draw a radius from the center of the Earth to the North Pole.

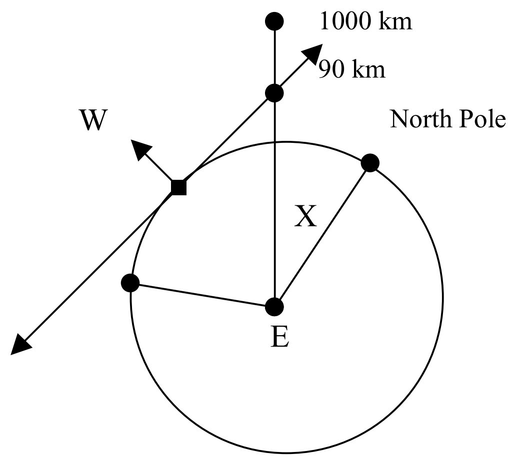


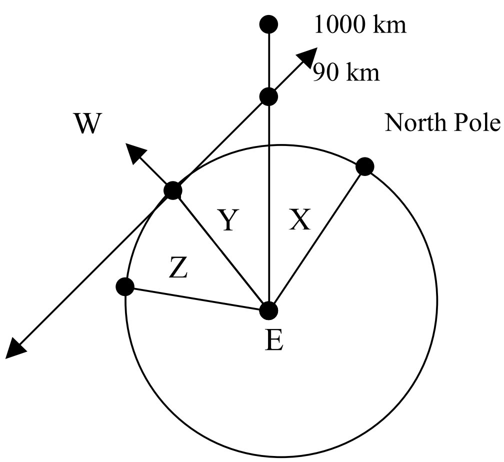
Step 3: Draw a line segment to connect the center E with the point at 90 km. The total length of the line segment will be the height. Label the angle X degrees.



Step 4. Using the height as a side, draw a 65 degree angle counterclockwise.

Step 5. Draw a tangent through the circle and the point at 90 km in the aurora region. Label the point that it intersects the circle as point W (Note: this tangent line is perpendicular to the edge of the circle).





Step 6. Draw a radius connecting point W to the center. This divides the 65 degree angle into two new angles. Label one angle Y and the other angle Z (note: the two angles are not congruent).

Problems and Questions:

1. What are the directions used to determine?
2. How do the diagrams help to clarify the directions for each step?
3. What does the word perpendicular in step five indicate?
4. In step 1, how can the center of the Earth be located?
5. If the Earth's radius is 6378, and the aurora region is 90 to 1000 km, what is the total height from the center of the Earth to the top of the aurora region?
6. Radius EW is perpendicular at point W. Find angle Y and angle Z.
7. Using the directions, construct the geometric figure.

Activity 4 Estimating Heights with a Clinometer

A clinometer is a simple-to-make instrument which lets you estimate the height of an object (building, tree, flag pole) by using the properties of a right-triangle.

Objectives:

Students will apply direct measurement of angles and length to determine height using the tangent ratio and the clinometer (a measuring tool).

Benchmarks:

6-8 Models are often used to think about processes that happen too slowly, too quickly or on too small a scale to observe directly, or that are too vast to be changed deliberately.

9-12 Find answers to problems by substituting numerical values in simple algebraic formulas.

9-12 Make and interpret scale drawings

Materials for the lesson:

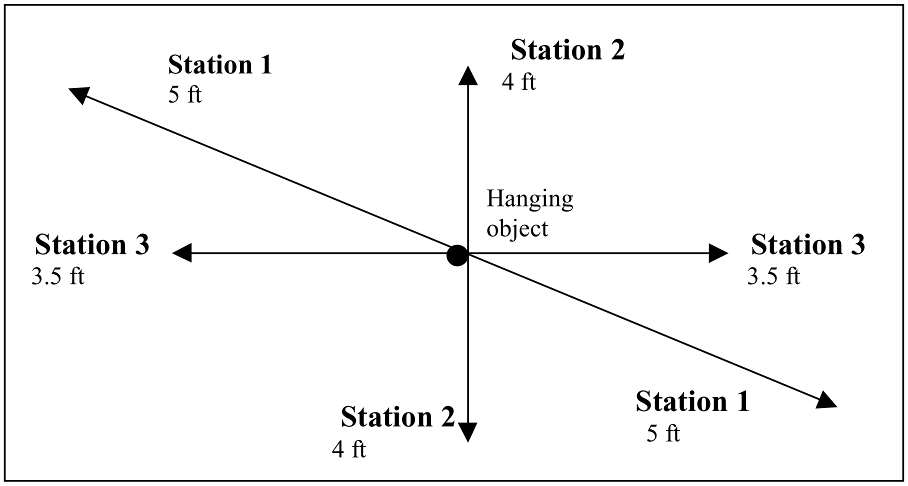
Rulers or yardsticks
An object to hang
A big X to hang under the object
Clinometers
Calculators – degree mode
Tangent table (optional if calculator is not available)
Graph paper or drawing paper
Student worksheet
Student Clinometer Activity Sheet
Teacher Demonstration Examples (Transparency)
Teachers scaled drawing
Ladder for the teacher
Roll of yarn
Scissors
Station marking items (paper taped to the floor indicating use this point here)
Ducked Tape

Extension: Have students measure the height of a tree or flagpole using the clinometer.

Procedure:

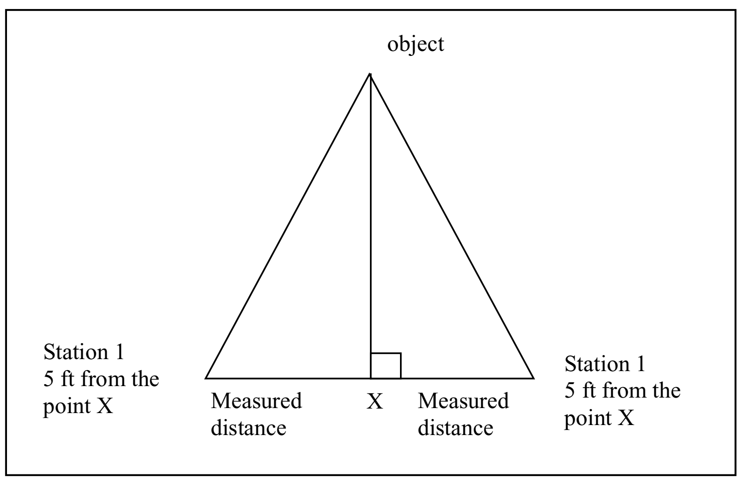
Step 1: Hang an object high from the center of the classroom. A big X can be taped to the floor so that the object hanging from it is directly under it. Based on the number of students in the class, locate enough stations so that each group will make at least two measurements from opposite sides of the room. Students will measure the distance out from the point right under the object, or the teacher could have already located the corresponding points. This is teacher discretion. In either case, vary the length of the distance for each station from where the student will stand to measure with the clinometer and the object. For instance, Station 1 is located five feet out from the point directly under the object while Station 3 is located 3.5 feet away from the point beneath the hanging object.

See the following figure for an example of the station set up. Note: groups may share a station since they could be on opposite sides of the room measuring.



Students completing Station 1 need to measure out five feet in both directions from the hanging object towards opposite sides of the room. The teacher may opt to tape yarn in lines through the point directly under the hanging object. This will provide the students with a direction guide.

Students will need to measure the distance to a point designated a certain distance from the location under the object. **Reminder**, a big X can be taped to the floor so that the object hanging from it is directly under it. Therefore, the triangle for Station 1 would be drawn as follows:



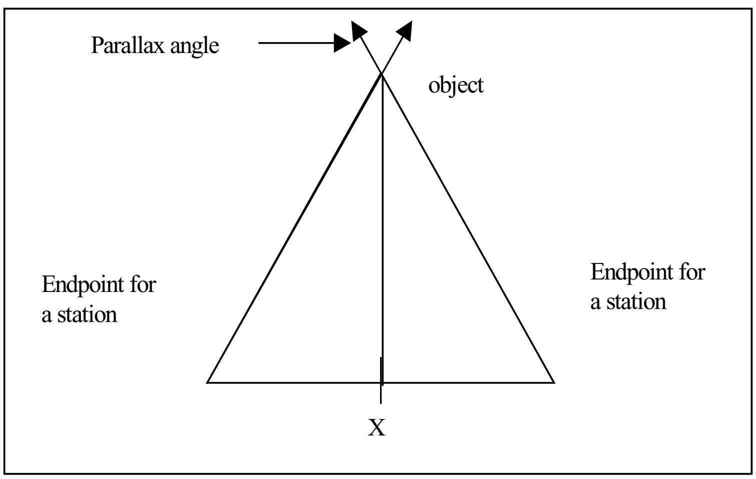
Students would have to determine the appropriate scale based on the individual classrooms.

Step 2: The teacher will have to prepare a scale drawing for one of the stations to use for discussion purposes in Step 8. Use the above diagram as a model based on your classroom.

Step 3: Using the Clinometer Instructions, students construct the clinometer. Another option is for the teachers to have the clinometers already constructed or to use store bought clinometers. The actual construction provides a hands on component prior to the actual measuring activity.
Step 4: Teacher guides the students through the teacher directed activity (see Teacher Demonstration Examples and Student Worksheet). This provides students with exposure to the process they will perform when determining the height of the object in the room. Teacher may opt to demonstrate location and clinometer as a visual model while completing the examples.
Step 5: Assign student groups to the stations that they will measure. Provide time for the students to complete their measurements, calculate the height, and check for reasonableness of their answer. Students record their answers on the Student Clinometer Activity Sheet. Teacher monitors measurements and calculations.
Step 6: The whole group discusses the possible answer as to how high the object is hanging and a what a possible scale diagram might look like from one of the stations.

Average the answers from each station.

Step 7: Select a station to be used as an example. The students from the group that used that station will be the helpers. Students use the yarn to go from the opposite endpoints of the station to each other to construct the base of the triangle. Students hold the endpoints. Another student gives the teacher, who is up on the ladder, two separate pieces of yarn while the students at the endpoints are given the other ends. Students duct tape the yarn to the floor. As a final step, the teacher uses another piece of string to construct the height of the triangle. The teacher duct tapes the yarn to the object, climbs down the ladder, removes the ladder, and duct tapes the other end of the 'height' yarn to the floor. What this step is doing, essentially, is to construct a visual model of the triangle that they will draw. (See diagram)



This is how the yarn should appear to the students when the teacher is on the ladder and students are holding the base vertices of the triangle.

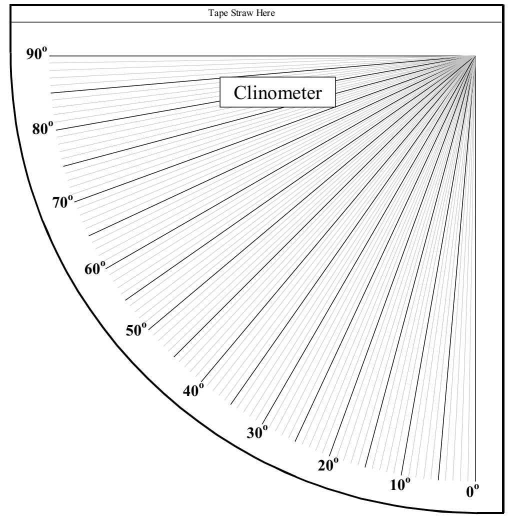
The teacher holds the yarn up near the object and the student groups hold the other ends in opposite endpoints of a station.. The triangle should be evident. The teacher can then extend the ends of the yarn to demonstrate the Parallax angle, and the property of vertical angles in a visible format.

Step 8: Using a piece of graph paper, students construct a scale drawing of the stations that they used to determine the height of the hanging object. Refer to Step 9 on the Student Clinometer Activity Sheet.
Step 9: Students share their scaled drawings.
Step 10: Teacher leads students in a discussion about how the scientists would use this method to determine the height of an aurora.

CLINOMETER INSTRUCTIONS

Materials to build a clinometer (one for each group of students):

Copy of the clinometer diagram
Straw
Scissors
Tape
13 centimeters of string
coin or weight
tagboard or cardboard
one hole punch

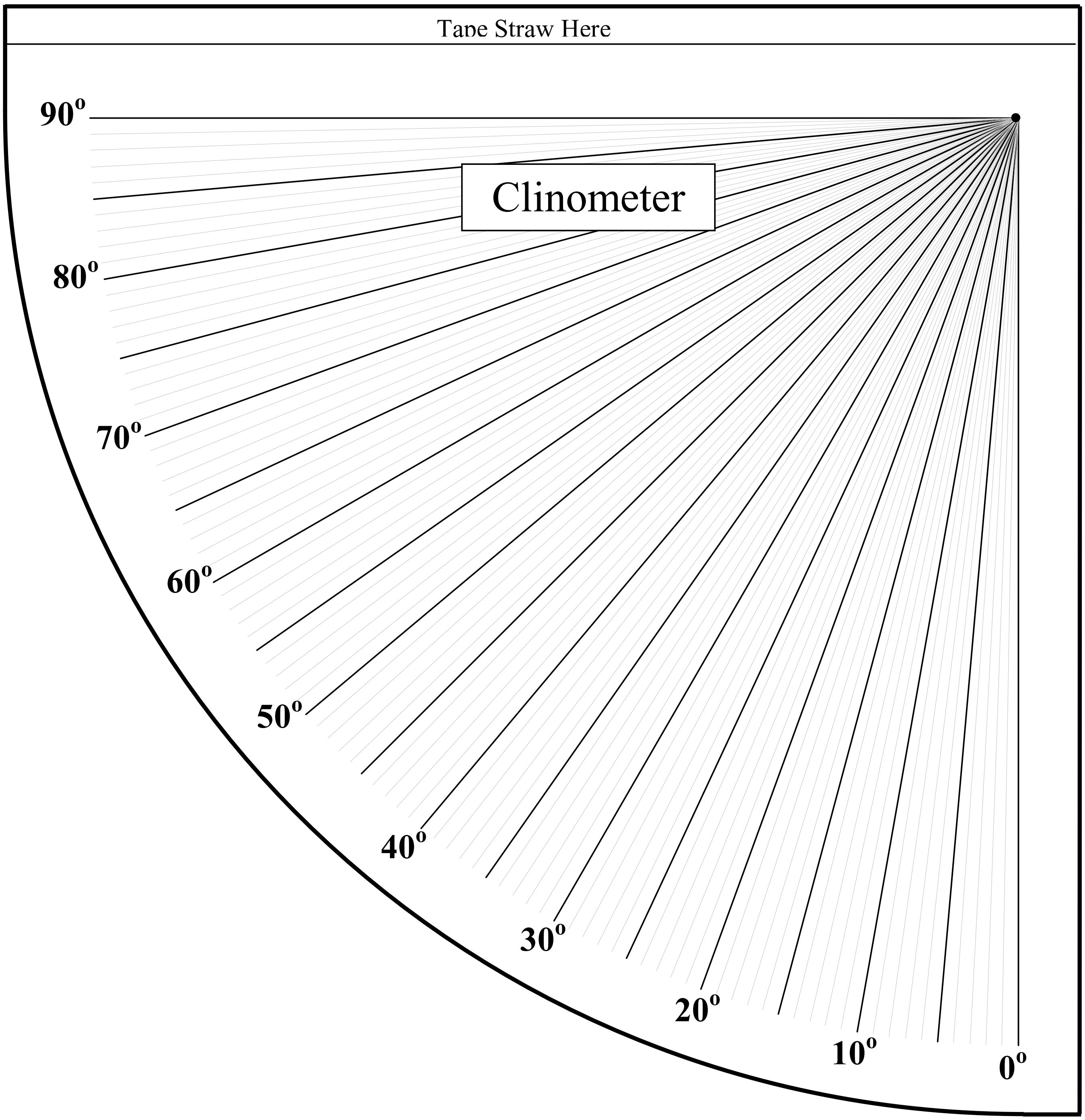


Instructions:

1. Mount a copy of the clinometer onto tagboard or cardboard. Cut out the clinometer.
2. Use a one hole punch or a push pin to poke a hole in the small circle in the upper right hand corner of the clinometer.
3. Put the piece of string through the hole in the clinometer. Allow about two or three centimeters of string on the backside of the clinometer. Tape the string securely to the back of the clinometer. Let the string on the other side dangle freely.
4. Tape a penny, nickel, or other coin to the end of the freely swinging piece of string. This will serve as a weight and act as a plumb line.
5. Lay the straw across the top of the clinometer. Cut off the excess straw. Tape the straw securely to the clinometer.

When using the clinometer, sight the top of the object through the straw. The plumb line remains perpendicular to the ground, and able to move freely, as the clinometer is moved to sight the object. The angle can be determined based on the string's location.

Sight from this end

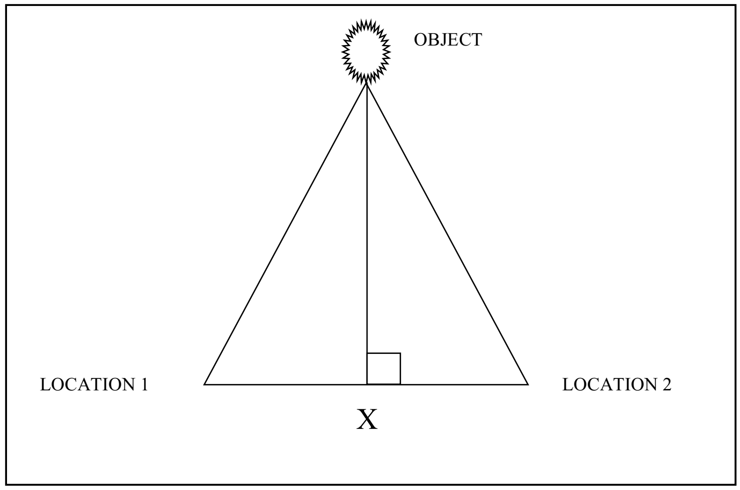


Teacher Demonstration Examples (Transparencies)

Student One is standing at Location 1

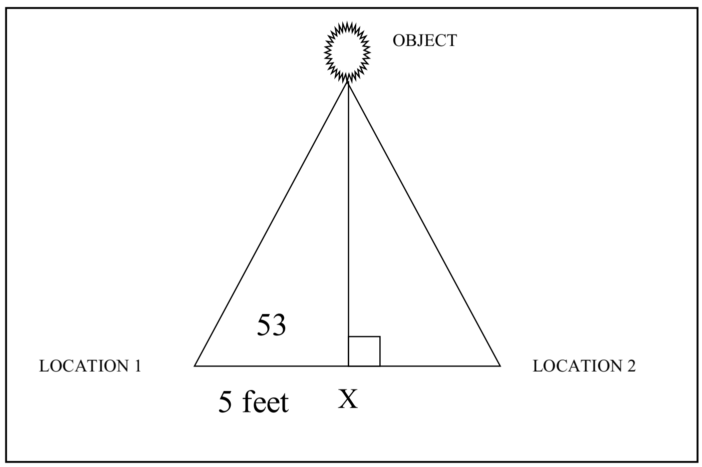
Student Two is standing at Location 2.

The goal is to determine how high the object is above the X. A diagram is provided.



PROBLEM 1:

Student One uses a clinometer and measures the angle to be 53 degrees. He measures the length from Location 1 to the X to be 5 feet. How high is the object based on his measurements?



Tan 53 = X / 5
(Tan 53) * 5 = X
6.64 feet = X

This is not the height. In order to finish calculating the height, it is necessary to add in the student's line of sight. The student measures his height from the floor to eye level and adds that amount back in to the height.

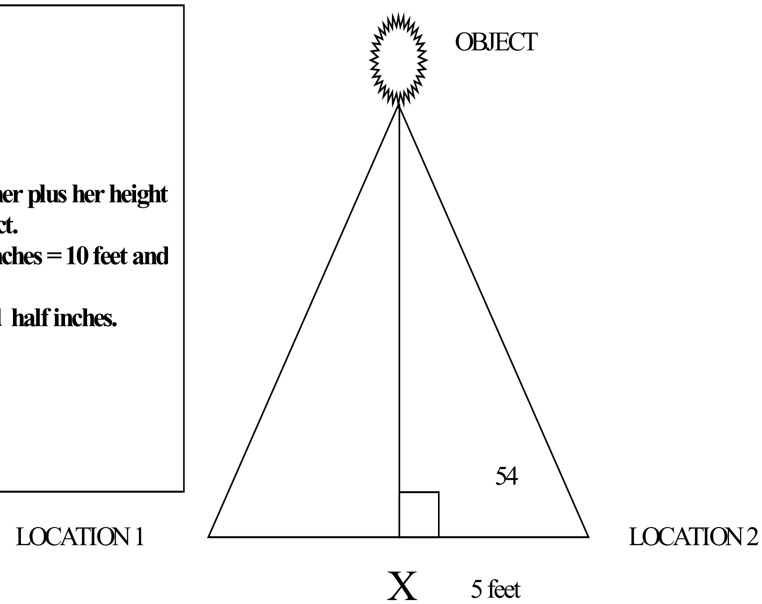
Student Ones' eye height is 4 feet.
The height is 6.64 feet + 4 feet = 10.64 feet.

What is 0.64 of a foot?
0.64 * 12 = 7.68 inches
Therefore, the height is approximately 10 feet 8 inches.

PROBLEM 2:

Student Two measures the distance from Location 2 to the X as 5 feet. Using the clinometer, she estimates the angle is 54 degrees. She is 4 and a half feet tall to her line of sight. How high is the object?

Tan 54 = X / 5
(Tan 54) * 5 feet = X
6.88 = X
Convert .88 to inches by using
.88 * 12 = 10.56 inches
Now add the two values together plus her height for the final height of the object.
6 feet + 10.5 inches + 4feet 5 inches = 10 feet and 15.5 inches
This simplifies to 11 feet 3 and half inches.



AVERAGE THE TWO ESTIMATED ANSWERS.

10 FEET 8 INCHES + 11 FEET 3.5 INCHES = 21 FEET 11.5 INCHES
= 263.5 INCHES

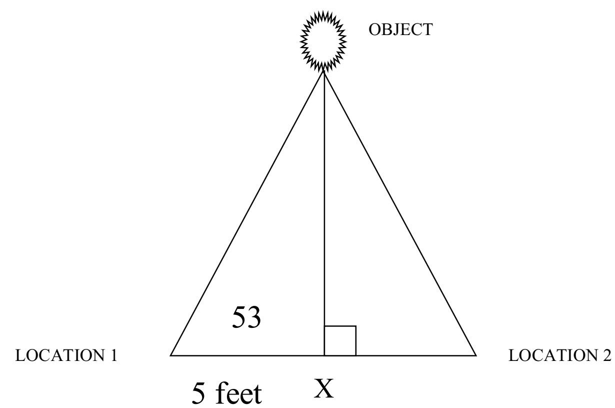
263.5 INCHES / 2 = 131.75 INCHES
= 10.97 FEET
= 10 FEET 11.6 INCHES

Name ________________________________ **Date** ____________

Problem 1:

Student One uses a clinometer and measures the angle to be 53 degrees. He measures the length from Location 1 to the X to be 5 feet. How high is the object based on his measurements?

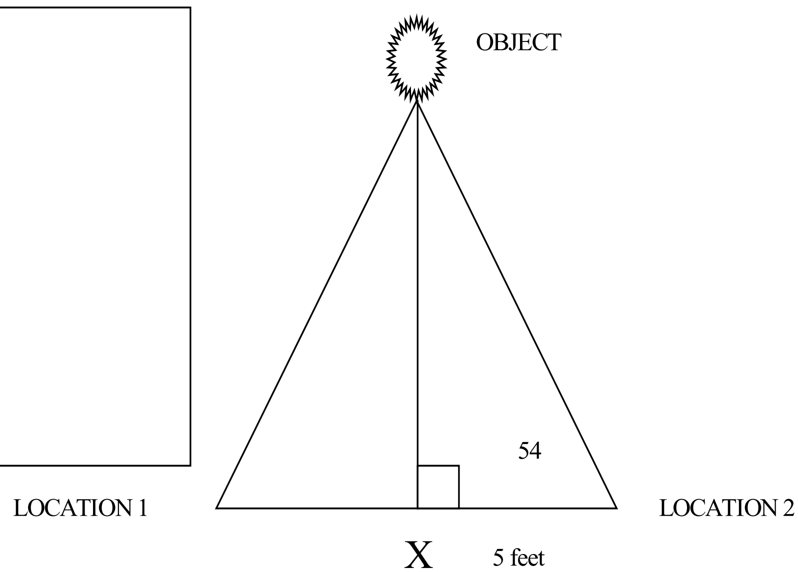
Show the calculations below.



Problem 2

Student Two measures the distance from Location 2 to the X as 5 feet. Using the clinometer, she estimates the angle is 54 degrees. She is 4 and a half feet tall to her line of sight. How high is the object?

Show the calculations below.



Average the two answers to obtain a closer estimate.

Student Clinometer Activity Sheet

SIGHTER________________________
RECORDER______________________
MEASURER______________________
CALCULATOR___________________

STEP 1: Decide which person will perform each of the above tasks.

STEP 2: Locate one of the station numbers that you were assigned.

STEP 3: Measure the distance in feet from the X to your station. Record the measurement in the table below.

STEP 4: Measure the eye level of the sighter from the floor to eye level. Record the data in the table below.

STEP 5: Use the clinometer to locate the top of the object. The measurer will need to determine the angle reading on the clinometer. Record the angle reading in the table.

STEP 6: Repeat the process above at the second assigned station recording the results in the table below.

STEP 7: Use the tangent ratio and the previous examples that were completed with teacher assistance to determine the height of the object.

Station Number	**Clinometer Reading**	**Length to the X (in feet)**	**Sighting Students eye height**

For each station fill in the following measurements for your calculations.
TAN (angle measure) = (the missing height) / (the length to the X)
TAN (______) = (the missing height) / (________)
TAN (_______) (_______) = (missing height)
Next add in the height of the sighter.
(missing height) + (height of the sighter) = (total height of the object)
The estimated total height of the object is _______________________ feet.

STEP 8: Average the results from all of the stations to obtain a closer estimate of the height of the hanging object.

STEP 9: Using a piece of graph paper, make a scale drawing of the two stations and the object.

Activity 5 How High Up are Aurora?

For thousands of years, people living at northern latitudes had no idea how high up the Aurora Borealis was located. All you could see from any particular vantage point was a curtain of light. There wasn't much about its shape that gave you any clue to how high up it actually was. The aurora could be 1 kilometer or 10,000 kilometers above the ground and there was no real way to tell. Before the advent of photography in the 1880's, auroral observers tried to determine the height of aurora by the method of triangulation. One of the earliest of these measurements was made by the French scientist Jean-Jacques d'Ortous de Mairan between 1731 and 1751. From two stations 10-20 km apart, observers measured the angle between the ground and a specific spot on an aurora. From the geometry of the triangle, they estimated that aurora occurred between 650 - 1,000 km above the ground.

Benchmarks:

Find answers to problems by substituting numerical values in simple algebraic formulas.
Understand that writing incorporates circle charts, bar charts, line graphs, tables, diagrams, and symbols.
Technology is essential to science for such purposes as access to outer space, sample collection, measurement, storage, and computation.

Objectives:

Students will apply the concept of triangulation in a variety of problem solving situations.

Teacher Answer Key:

1. Tan(60) = (X divided by 57.75)
   Tan(60) * 57.75 = X
   100.0259 = X

2. Part 1
   Tan(87.15) = (X divided by 5)
   Tan(87.15) * 5 = X
   100.435 = X
   Part 2
   Tan(84.3) = (X divided by 10)
   Tan(84.3) * 10 = X
   100.187 = X
   Part 3
   Tan(80.1) = (X divided by 17.5)
   Tan(80.1) * 17.5 = X
   100.270 = X
   A good conjecture is that the height of all of the triangles is approximately 100 km.

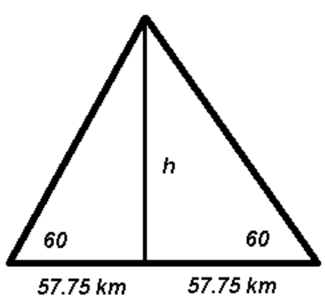
Teacher Answer Key (cont'd):

3. 100.0259 + 100.435 + 100.187 + 100.270 = 400.9179
   400.9179 divided by 4 = 100.229475
   Rounded to the nearest unit = 100 km.
4. Dr. Made A. Mistake missed a digit in using the angle measurement.
   These are his calculations:
   Tan(5) = (X divided by 8.75)
   Tan(5) * 8.75 = X
   .765 = X
   What he should have done was the following:
   Tan(85) = (X divided by 8.75)
   Tan(85) * 8.75 = X
   100.013 = X

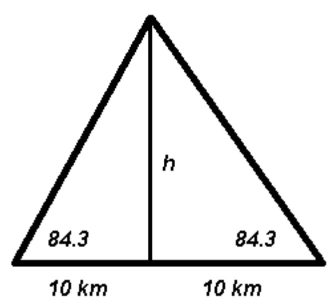
5. Dr. Nada Written Down can use the inverse tangent to find the missing angle measure. Inverse tangent of (100 divided by 7.5) = 85.7 degrees.

6. Dr. Flipped D. Numbers transposed the angle measure. He used 85.0 instead of 80.5 degrees.
   Tan(85.0) = (X divided by 16.75)
   Tan(85.0) * 16.75 = X
   191.453 = X
   Corrections:
   Tan(80.5) = (X divided by 16.75)
   Tan(80.5) * 16.75 = X
   100.094 = X

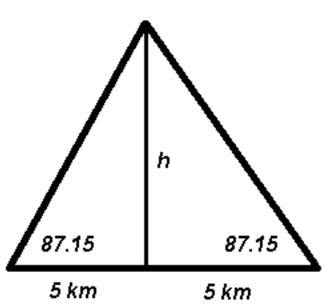
Problem 1 :



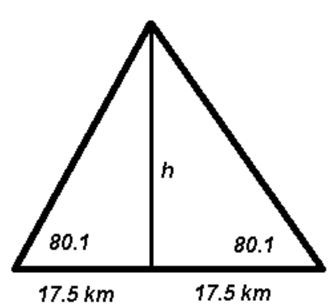
Problem 2a :



Problem 2b :



Problem 2c :



7. The missing angle measure is **30 degrees**. The two angles sum is **30 + 30 = 60 degrees**. The measure of angle P is **60 degrees**.

8. The missing angle measure is **180 – 84.3 – 90 = 5.7 degrees**. The two angles sum is **5.7 + 5.7 = 11.4 degrees**. The measure of angle P is **11.4 degrees**.

9. The measure of the Parallax angle is calculated as follows (see figure below):

180 – 87.15 – 90 = 2.85
2.85 * 2 = 5.7
Therefore the measure of the Parallax angle is 5.7 degrees.

10. The measure of the Parallax angle is calculated as follows (see figure below):

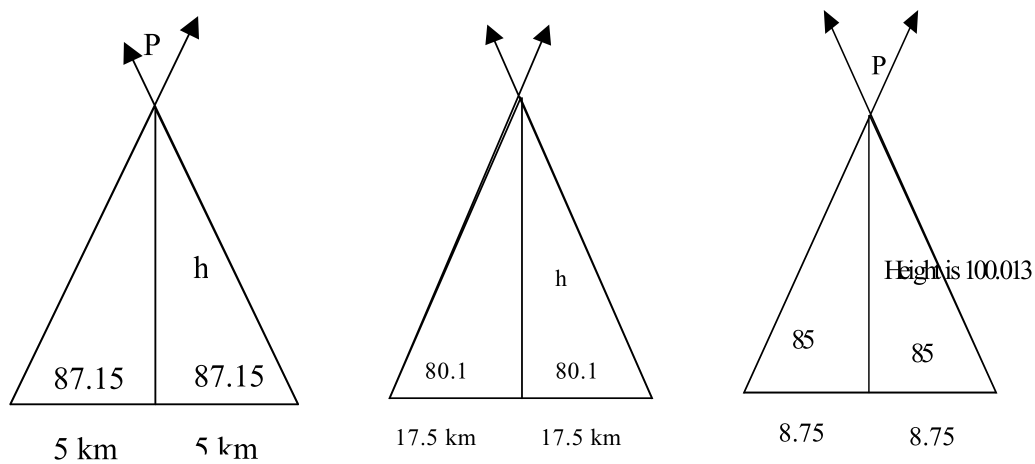
180 – 80.1 – 90 = 9.9
9.9 * 2 = 19.8
Therefore the measure of the Parallax angle is 19.8 degrees.

11. The measure of the Parallax angle is as follows (see figure below):

180 - 85 - 90 = 5
5 * 2 = 10
Therefore the measure of the Parallax angle is 10 degrees.

12. The parallax angle is calculated as follows:

180-85.7 - 90 = 4.3
4.3 * 2 = 8.6 degrees.
Therefore the measure of the Parallax angle is 8.6 degrees.



Problem 9 Problem 10 Problem 11

Name ______________________________________ **Date** ____________

Direction: Construct or draw the figure and solve for the given unknown.

1. Draw an isosceles triangle with base angles of 60 degrees and a base length of 115.5 km. Let 21 km = 1 cm. Locate the midpoint and bisect the base. What is the approximate height of the triangle? Explain your answer using mathematics.

2. Sketch the following figures (note: not to scale).
   A. An isosceles triangle with base angles of 87.15 degrees and the base is 10 km. Locate the midpoint of the base and draw the altitude. Calculate the height.
   B. A triangle with base angles of 84.3 degrees and the length of the base is 20km. Calculate the height.
   C. A triangle with base angles of 80.1 degrees and a base of length 35. Determine the height.

   Make a conjecture (a guess) about the calculated heights.

   Careful observations of the lowest limits to aurora show that they rarely are less than 90 km above the ground. Some legends insist that they can touch the ground, but this is merely an optical illusion. Their tops, however, can sometimes exceed 1,500 kilometers. Auroras require very low density air in order to produce their light. If the air is too dense, as it is below 90 kilometers, the physical process that produces the light does not work. The atoms in the denser air collide faster than the time it takes for the atom to produce the light.

3. Suppose each of the four problems above were recorded by four different scientists studying the same aurora feature. Based on your calculations, what is the average height to the nearest unit?

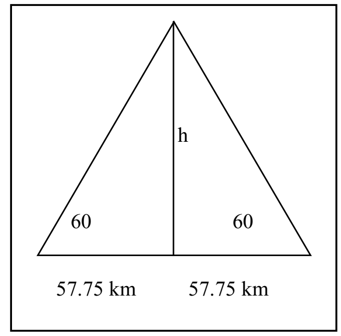
4. Dr. Made A. Mistake, a fifth scientist, was out of luck. He calculated the height to be 0.765 km. He measured the base angles to be 85 degrees and the length of the base was 17.5km. Show the correct calculations for the height and determine his mistake.

5. Dr. Nada Written Down, another aspiring young scientist, did not write down her calculations. She remembered that the height was 100 km and that the base length was 15 km. Can you determine the missing base angles?

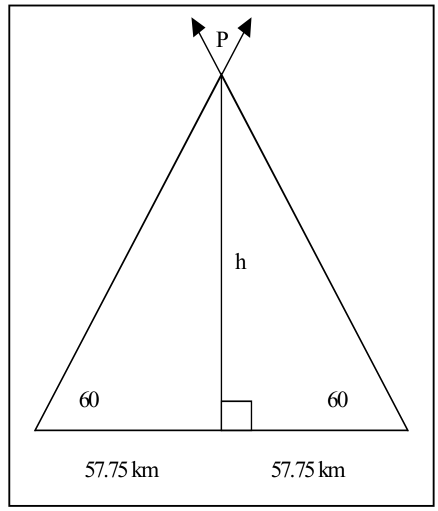
6. Dr. Flipped D. Numbers is having a tough time figuring out where the mistake is in the calculations. The base length was 33.5 km and the base angles were 80.5 degrees. The height that he determined was 191.45 km. How could he have made this mistake?

Name ____ Date _____________

7. To the right is the completed drawing for Problem 1.

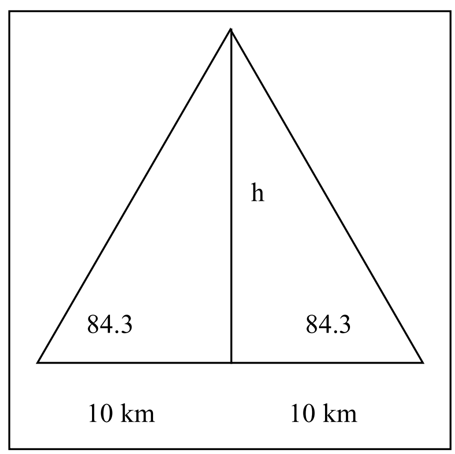


The legs have been extended to create angle P. This angle, P, is referred to as the Parallax angle. The height is perpendicular to the base. Since two angles are known for each of the two smaller triangles, and it is known that the sum of the angles of a triangle are equal to 180 degrees, the third missing angle measure for each triangle can be calculated.



The missing angle measure is ________. Since both angles at the top are congruent, then their sum is ______. These angles and angle P form vertical angles. Therefore, the measure of angle P is ________.

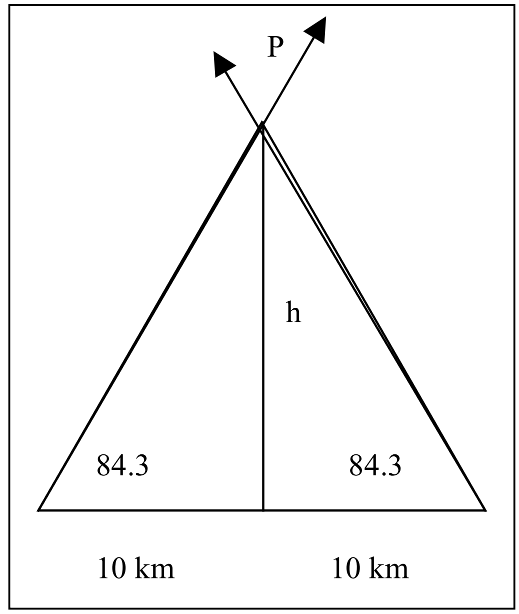
8. The completed drawing for Problem 2a is shown to the right.



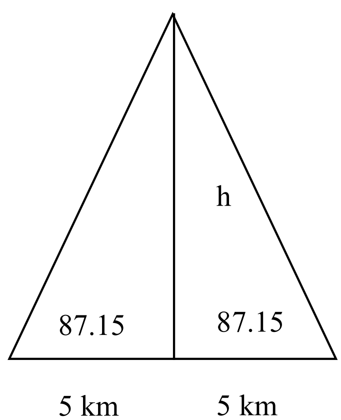
Name ____ Date _____________

The legs have been extended to create angle P. This angle, P, is the Parallax angle. The height is perpendicular to the base. Since two angles are known for each of the two smaller triangles, and it is known that the sum of the angles of a triangle are equal to 180 degrees, the third missing angle measure for each triangle can be determined.

The missing angle measure is _____. Since both angles at the top are congruent, then their sum is ______. These angles and angle P form vertical angles. Therefore the measure of angle P is _______.

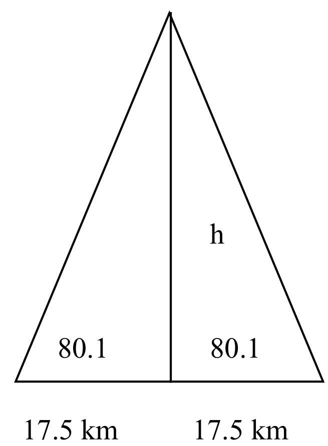


9. Below is the completed drawing for Problem 2b. Draw in the Parallax angle and then determine the measure of the Parallax angle.



Name ____ **Date** _____________

10. Below is the completed drawing for Problem 2c. Draw the figure showing the Parallax angle and then determine the measure of the Parallax angle.



11. Draw and label a diagram for Problem 4. Extend the drawing to include the Parallax angle. Determine the Parallax angle measure based on the given information and the correct answer for problem four.

12. Using Problem 5 determine the Parallax angle using any method.

Activity 6: Aurora Triangulation from Photographs

Parallax:

Stretch your arm out in front of your face with your thumb extended upwards. Now, close your left eye and note where your thumb appears in relation to objects in the distance. Now close your right eye and open the left. Note that the position of your thumb has shifted slightly to the right compared to where it was when only your left eye was open. This shift is known as parallax, and your brain uses this information to figure out how far things are away from you.

Beginning in 1909, the Norwegian scientist Carl Stormer used a similar technique to find out how high up aurora were located. Although many scientists had attempted to measure auroral heights before 1900, Stormer made the photographic process an exacting science by carefully designing procedures and mathematical techniques to minimize many different sources of experimental error. He used a network of cameras that simultaneously photographed the same auroral feature. The photographs from 10 different stations in Norway were combined in pairs with many different separations. These paired photographs were used to measure the parallax angle shifts. From these shifts, an average distance to different parts of an aurora could be found. Over 12,000 of these measurements were made by Stormer between 1909 and 1944, using specially-designed cameras with no moving parts so that they would not freeze-up during the very cold winter nights! In the days before the invention of modern insulated parkas, they wore thick fur clothing.

Objective:

The students will use real life pictures to determine Parallax angle shifts and use information calculated to determine auroral height.

Photograph:
Stormer (left) and an assistant posing with an aurora camera in Bossekop, Norway in 1910.

Benchmarks:

6-8 Technology is essential to science for such purposes as access to outer space, sample collection, measurement, storage and computation.
9-12 Distances and angles that are inconvenient to measure directly can be found from measurable distances and angles using scale drawings.
6-8 Models are often used to think about processes that happen too slowly, too quickly or on too small a scale to observe directly, or that are too vast to be changed deliberately.
9-12 Find answers to problems by substituting numerical values in simple algebraic formulas.
6-8 Understand writing that incorporates circle charts, bar graphs line graphs, tables, diagrams and symbols

Materials:

Pictures of the stars
Student worksheets
Calculator – degree mode
Metric Ruler
Vocabulary list

Procedures:

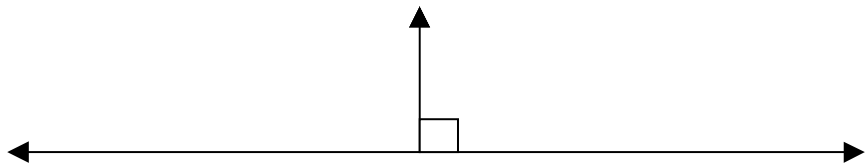
Step 1: Teacher introduces the vocabulary list to the students. These can be place on the overhead or on the chalkboard.

Step 2: Students work through the steps on the student worksheet. The activity can be completed by the student if the teacher is confident that they can perform the tasks, or the steps can be completed one at a time in pairs or groups. If the teacher opts to do this, it might be good to stop after each step or every two steps and discuss the results prior to completing more steps. The teacher may wish to have a transparency of the student worksheets and the stars to show how and fill in as the activity progresses.

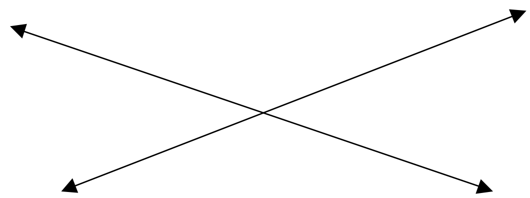
Step 3: Discuss the answers if not already completed.

Vocabulary List:

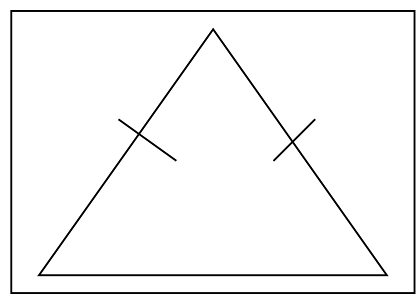
Perpendicular: two lines are perpendicular if the angle between them is 90 degrees.



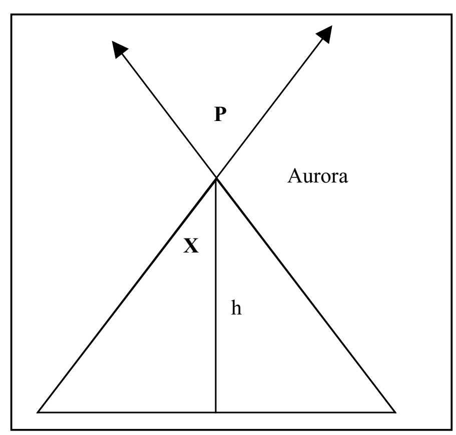
Vertical angles: Angles that share only one point. They are on opposite sides of the transversal.



Isosceles triangle: A triangle that has at least two congruent sides.



Parallax: The vertex angle P. Obtained from 180 minus the sum of the two base angles.



Name ______________________________ Date ____________

Station 1: This is a photograph taken at one observing station of an aurora that passed through the bowl of the Big Dipper (Ursa Major). The numbered stars are:

1...Dubhe
2...Mirak
3...Phecda
4...Megrez
5...Alioth
6...Mizar

Station 2: This is a photograph of the aurora in the Big Dipper (Ursa Major) taken at the same time from a second observing station 17. 6 kilometers from Station 1. Note that there is a shift in the location of the aurora between the two stations.

Name ____ **Date** _____________

STEP 1: Using the photographs, measure in millimeters the distance between the following points and complete the table.

Points to be measured	Distance in millimeters
Point 1 and 4	27 mm
Point 1 and 6	
Point 2 and 5	
Point 1 and 5	

STEP 2: The points that were measured are really stars in the sky. They make up a constellation known as the Big Dipper. Using the table below, determine the degrees based on the measurement above.

Pair of stars	Degrees
1 and 4	10
1 and 6	20.5
2 and 5	15.5
1 and 5	14.5

For Example:
Point 1 and 4 were measured to be 27 mm. Using the table in step 2, pair of stars 1 and 4 are 10 degrees. This means that the angular distance of these two stars in the sky is 10 degrees.

Step 3: Next it is necessary to calculate the image (pictures) scale based on the above information. In order to do so, use the following formula where S = the scale.

For Example:
S = (Degrees) divided by the (measured millimeters)
S = (10 degrees) / (27mm)
S = 0.37
Identify the degrees for each of the other star pairs.
Use the formula to calculate the scale for the other pairs of stars.

Step 4: Use the formula to calculate the scale for the other pairs of stars and complete the following chart. The first one is completed.

Pairs of Stars – Official Name	Scale
1 and 4 -- Dubhe-Mehrez	0.37
1 and 6 -- Dubhe-Mizar	
2 and 5 -- Merak-Alioth	
1 and 5 -- Dubhe-Alioth	

Name ____ Date _____________

STEP 5: In this case, the values do not have a significant difference. However, in order to be more accurate in determining the scale, it is a good idea to average the results. Therefore, average the values in the scale column.
(0.37 + ____ + ____ + ____) / 4 = _______ **IMAGE SCALE**

STEP 6: Next, pick a feature that is in the aurora and measure the distance to the edge of the aurora in each photo.
For Example:
Select point 4. Measure the horizontal distance to the edge of the photo for this point in each photograph. The edge of the Aurora in photo one is _____ mm away from point 4 and the edge of the Aurora is _____ mm away from the edge of the Aurora in photo two. Now subtract the two measurements in order to obtain the Parallax shift.

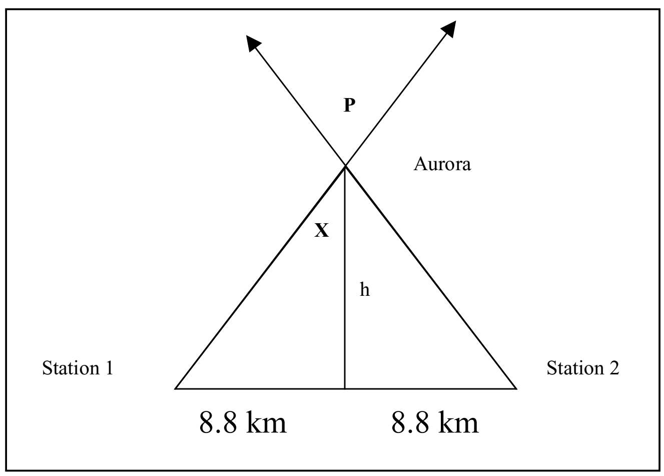
Photo two ______ mm − Photo one _____ mm = ________ PARALLAX SHIFT
This value should be typically the same for each point in the photo.

STEP 7: Now that the image scale has been calculated and the Parallax shift is determined, these two values can be multiplied together to obtain the number of degrees in the Parallax angle.
IMAGE SCALE * PARALLAX SHIFT = PARALLAX ANGLE

STEP 8: when all of the above steps are completed, they can be applied to determine the Auroral height. Station 1 and Station 2 are 17.6 kilometers apart. Using the Parallax angle, P in the diagram below, use properties of vertical angles and the tangent ratio to determine the height, h. (note: the height is perpendicular to the base)

First, divide the Parallax angle in half to determine angle X. Then use the fact that the sum of the angles of a triangle is 180 degrees to find the missing base angle. Last, apply the tangent ratio to determine the height of the Aurora.

The height of the Aurora is __________ km.



Teacher Answer Key

STEP 1: Using the photographs, measure in millimeters the distance between the following points and complete the table.

Points to be measured	Distance in millimeters
Point 1 and 4	27 mm
Point 1 and 6	**52 mm**
Point 2 and 5	**42 mm**
Point 1 and 5	**41 mm**

STEP 2: The points that were measured are really stars in the sky. They make up a constellation known as the Big Dipper. Using the table below, determine the degrees based on the measurement above.

Pair of stars	Degrees
1 and 4	10
1 and 6	20.5
2 and 5	15.5
1 and 5	14.5

For Example:

Point 1 and 4 were measured to be 27 mm. Using the table in step 2, pair of stars 1 and 4 are 10 degrees. This means that the angular distance of these two stars in the sky is 10 degrees.

Step 3: Next it is necessary to calculate the image (pictures) scale based on the above information. In order to do so, use the following formula where S = the scale.

For Example:

S = (Degrees) divided by the (measured millimeters)

S = (10 degrees) / (27mm)

S = 0.37

Identify the degrees for each of the other star pairs.

Use the formula to calculate the scale for the other pairs of stars.

Step 4: Use the formula to calculate the scale for the other pairs of stars and complete the following chart. The first one is completed.

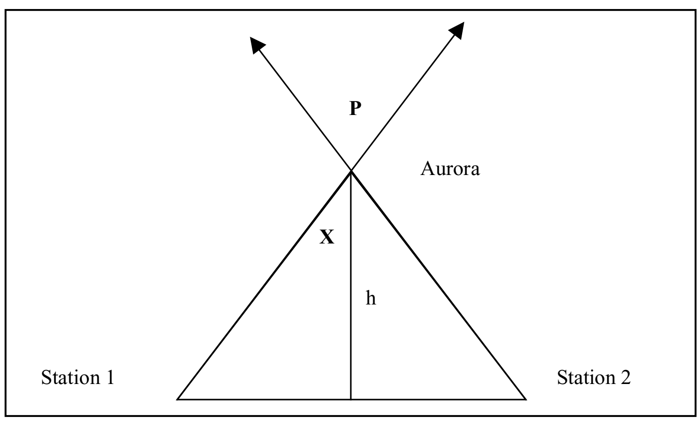
Pairs of Stars – Official Name	Scale
1 and 4 -- Dubhe-Mehrez	0.37
1 and 6 -- Dubhe-Mizar	**0.39**
2 and 5 -- Merak-Alioth	**0.37**
1 and 5 -- Dubhe-Alioth	**0.35**

STEP 5: In this case, the values do not have a significant difference. However, in order to be more accurate in determining the scale, it is a good idea to average the results. Therefore, average the values in the scale column.
(0.37 + **0.39** + **0.37** + **0.35**) / 4 = **0.37 IMAGE SCALE**

STEP 6: Next, pick a feature that is in the aurora and measure the distance to the edge of the aurora in each photo.
For Example:
Select point 4. Measure the horizontal distance to the edge of the photo for this point in each photograph. The edge of the Aurora in photo one is <u>2 mm</u> away from point 4 and the edge of the Aurora is <u>22 mm</u> away from the edge of the Aurora in photo two. Now subtract the two measurements in order to obtain the Parallax shift.
Photo two 22 mm - Photo one 2 mm = 20 mm PARALLAX SHIFT
This value should be typically the same for each point in the photo.

STEP 7: Now that the image scale has been calculated and the Parallax shift is determined, these two values can be multiplied together to obtain the number of degrees in the Parallax angle.
IMAGE SCALE * PARALLAX SHIFT = PARALLAX ANGLE
0.37degrees per mm * 20 mm = 7.4 degrees

STEP 8: when all of the above steps are completed, they can be applied to determine the Auroral height. Station 1 and Station 2 are 17.6 kilometers apart. Using the Parallax angle, P in the diagram below, use properties of vertical angles and the tangent ratio to determine the height, h. (note: the height is perpendicular to the base)



First, divide the Parallax angle in half to determine angle X. **7.4 / 2 = 3.7 degrees** Then use the fact that the sum of the angles of a triangle is 180 degrees to find the missing base angle. **180 – 90 – 3.7 = 86.3 degrees** Last, apply the tangent ratio to determine the height of the Aurora.
Tan (86.3) = (height)/ 8.8 km
Tan (86.3) (8.8 km) = height
136.08km is the height of the aurora.
The height of the Aurora is **approximately 136 km to the nearest km.**

Activity 7 Auroral Magnetism from the Ground

Introduction:

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 effects can also be easily detected on the ground. During the last 100 years, many ‘magnetic observatories’ have been commissioned around the world to monitor 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 Earth.

Objectives:

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

Procedure:

1) Plot the location of each magnetic observatory on a map of Canada. Label each station number next to the plotted point.

Materials:

5-station Data Sheet.
Calculator
Map of Canada

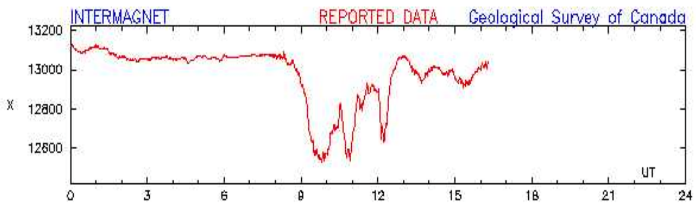
2) Analyze the magnetic intensity plot for each station and identify the largest difference in change in activity on the plot. The units of magnetic intensity are in nano-Teslas. One nanoTessla (nT) is equal to one billionth of a Tessla.

3) Find the absolute magnitude of the change for each station. Write the number below the location of the station on the map.

4) 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?

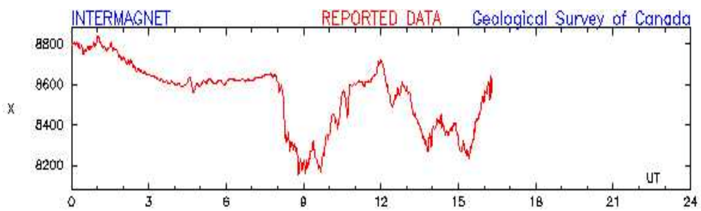
Student Data Sheet



Station 1: Meanook
(54.6 North , 113.3 West)

The largest range in 'X' is

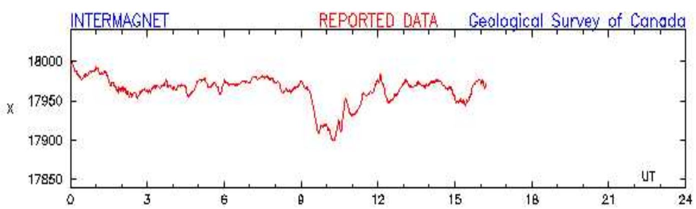
_______________ nano-Tesslas



Station 2: Fort Churchill
(58.8 North, 94.1 West)

The largest range in 'X' is

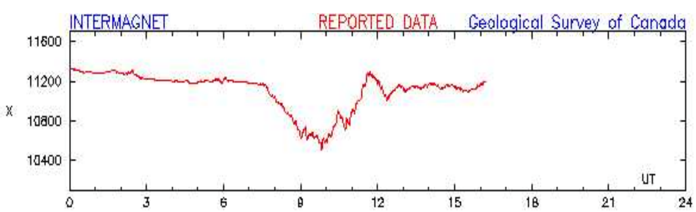
_______________ nano-Tesslas



Station 3: Victoria
(48.5 North, 123.4 West)

The largest range in 'X' is

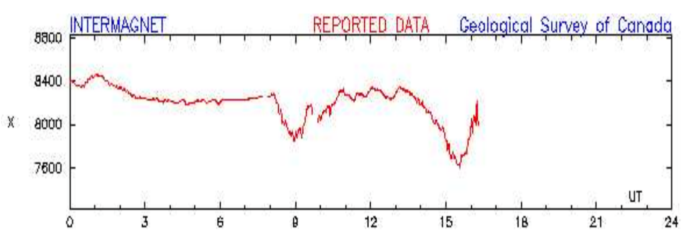
_______________ nano-Tesslas



Station 4: Poste-de-la-Baleine
(55.3 North, 77.8 West)

The largest range in 'X' is

_______________ nano-Tesslas



Station 5: Yellowknife
(62.4 North, 114.5 West)

The largest range in 'X' is

_______________ nano-Tesslas

The vertical axis is Earth's magnetic field strength measured in nano-Tesslas. The horizontal axis is the time in hours since midnight.

Teacher's Answer Key:

For each student, they will find the range of the variable 'X' plotted for each station during the three-hour period from 9:00 to 12:00 inclusive.

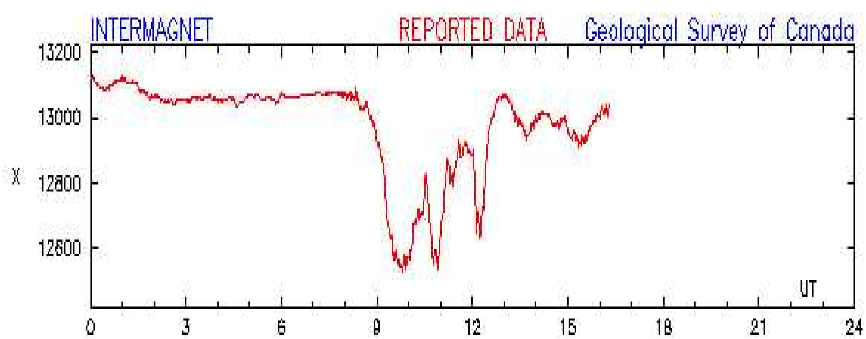
For example, the plot below is for Station 1 recorded on July 12, 2002 and the vertical tic marks occurs every 200 nano-Tesslas.

We can estimate that between 9:00 and 12:00 the magnetic field 'X' component varied from a minimum of 12500 nanoTesslas to a maximum of 12900 nanoTesslas.

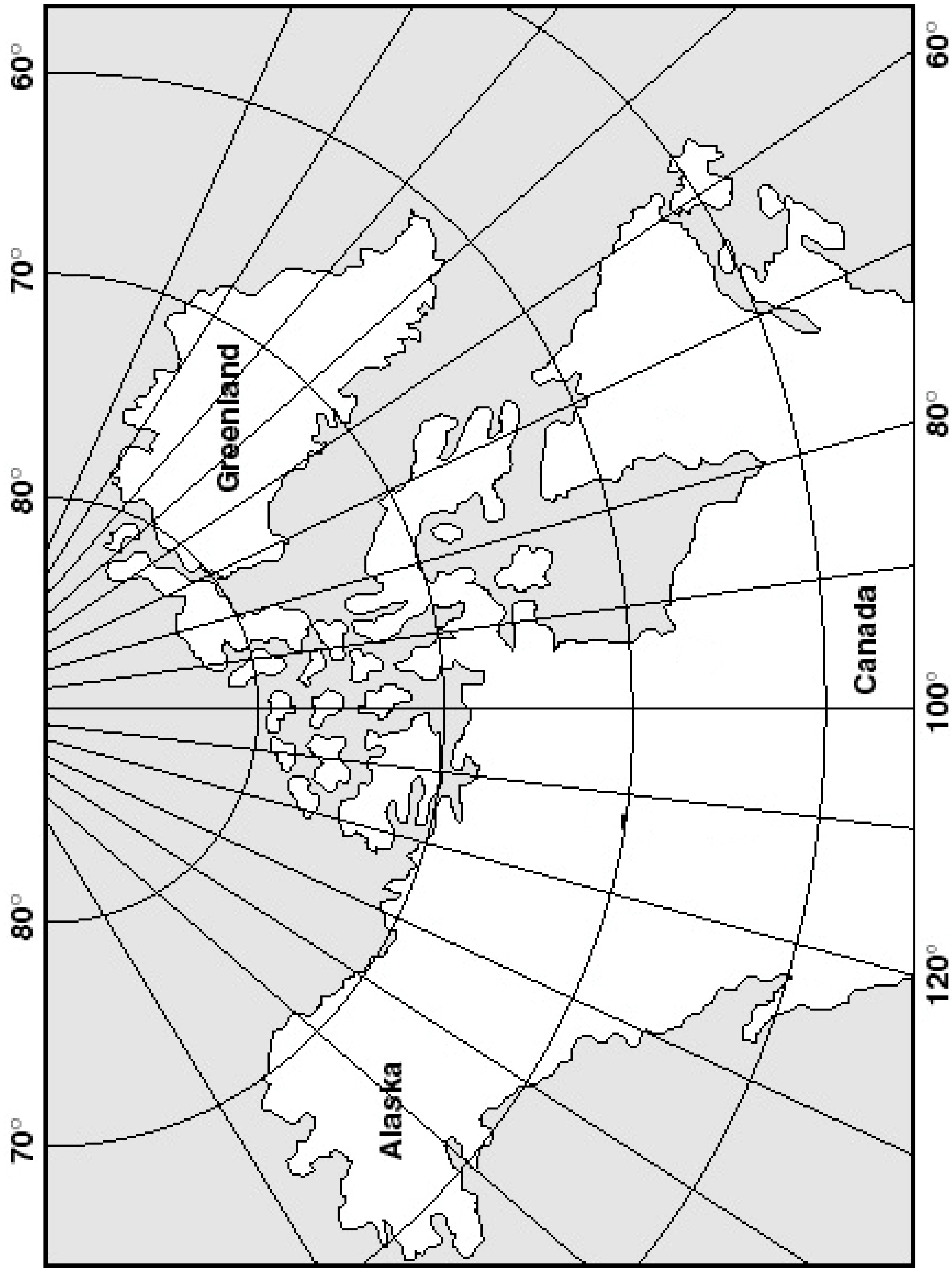
The range of the magnetic variation is 12900-12500 = 400 nanoTesslas for Station 1. Here are the answers for all five stations:

Station 1 =	12900 - 12500	= 400 nT
Station 2 =	8700 - 8200	= 500 nT
Station 3 =	17980 - 17900	= 80 nT
Station 4 =	11250 - 10600	= 650 nT
Station 5 =	8300 - 7900	= 400 nT

Students may obtain even more accurate estimates by measuring the scale on the vertical axis of each plot by using a millimeter ruler and determining the 'nanoTesslas per centimeter' constant and then interpolating the vertical axis.



For additional real-time plots from observatories in Canada, visit:
http://www.geolab.nrcan.gc.ca/geomag/e_digdat.html


60°
70°
80°
80°
70°
Greenland
Alaska
Canada
60°
80°
100°
120°

Activity 8 How to Predict an Aurora

Up until the mid-1800's, no one really knew why aurora occur. As you can imagine, this makes it very hard to predict when they will be seen next. By combining different kinds of data, scientists in the late 1800's and early 1900's began to see patterns emerge, and were soon able to use them to predict when aurora would occur. For example, during an aurora, Earth's magnetic field changes slightly, and this can be detected on the ground as a 'magnetic storm'. For some of the most severe storms, even a simple compass can sometimes work to sense these large changes in the field which can last for several hours. With the help of dozens of specially-designed observatories around the world, especially in the northern and southern polar regions, scientists have created a magnetic storm scale that is much like the scales that other scientists use to measure hurricanes and tornadoes. The scale was designed in 1939 by the German physicist Julius Bartles and we now call it the 'Kp' scale. Another, easier to use, 'Ap' index is directly related to the amount of change in the magnetic field, and is measured in units of nano-Tesslas.

In the previous activity, we measured the largest magnetic change that occurred in a three-hour period on July 12, 2002 based on the measurements from five magnetic observatories. Every three hours, the observatories identify the largest change in Earth's magnetic field at ground level, then by averaging these numbers together with the several dozen other observatory measurements around the globe, an average magnetic storm value in nano-Tesslas is found. This is then converted into the Kp index by using a table.

When an aurora is occurring, the Kp index is usually higher than about 6 or 7. Whenever these values are exceeded during any 3-hour period, this usually means that an aurora is in progress or will soon be visible.

Benchmarks:

6-8 Technology is essential to science for such purposes as access to outer space, sample collection, measurement, storage and computation.
6-8 Most of what goes on in the universe involves some form of energy being transformed into another.
6-8 Graphs can show a variety of possible relationships between two variables.
9-12 Sometimes scientists can control conditions in order to obtain evidence. When that is not possible, they try to observe as wide a range of natural occurrences as possible to be able to discern patterns.
9-12 Increasingly sophisticated technology is used to learn about the universe.
9-12 Use charts and graphs in making claims in oral and written presentations.

Objective:

The students read and interpret graphs, average data values, and use the results to draw conclusions based on the data.

Materials:

Calculator
Access to the internet

Procedures:

1. Provide each student with a copy of the student page.
2. Guide students through the May 27, 2002 exercise on the teacher page.
3. Permit time and access to the internet to complete the exercises.
4. Discuss the student results and compare their analysis of the data.
5. Provide time for the students to develop a written summary.
6. Students can present their summary.

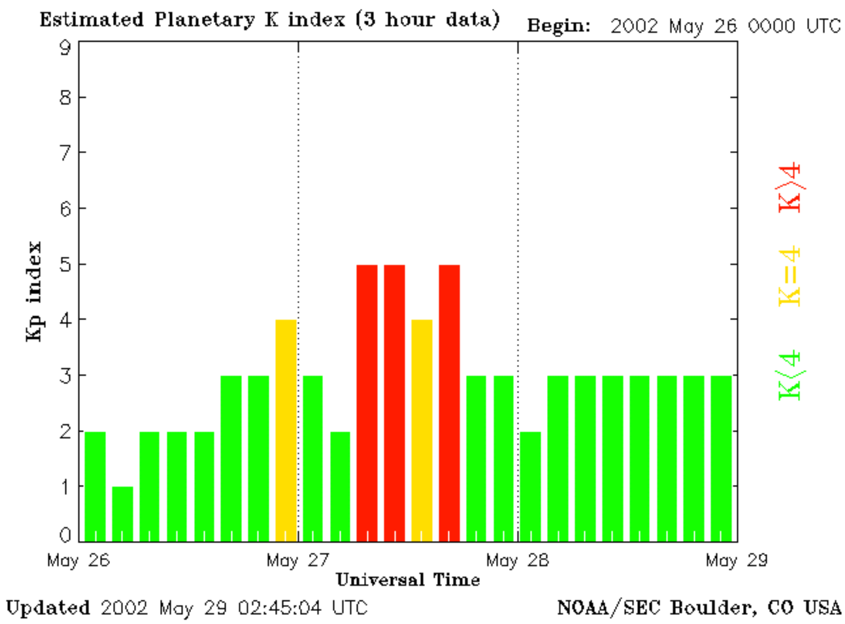
Selected Answers:

1...April 19, 2002
Ap= (27 + 27 + 27 + 80 + 80 + 48 + 48 + 48)/ 8 Ap = 48 Kp = 5
2...April 20, 2002
Ap= (140 + 140 + 140 + 80 + 27 + 27 + 27 + 7)/8 Ap = 74 Kp = 5
3...July 13, 2000
Ap= (7 + 7 + 15 + 48 + 140 + 48 + 7 + 15)/ 8 Ap = 36 Kp = 4
4...July 14, 2000
Ap=(27 + 15 + 27 + 27 + 27 + 80 + 48 + 27)/8 Ap = 35 Kp = 4
5...July 15, 2000
Ap= (27 + 27 + 48 + 48 + 80 + 400 + 400)/ 8 Ap= 129 Kp = 6

Conclusions:

Students should note that when the Ap value is larger, there is a much more observable auroral oval in the IMAGE data. The May 27, 2002 date had very little noticeable auroral oval and a low Ap value of 28. In contrast, in 2000 on July 14 and 15th there was a very significant oval and a very high A value of 129 . Furthermore, on the Kp index graphs, there were a number of Kp values that were 9 in July 2000 versus nothing higher than a 5 in May 2002.

Current Kp index plots are available at:
http://www.sec.noaa.gov/rt_plots/kp_3d.html



Kp	Ap
0	0
1	3
2	7
3	15
4	27
5	48
6	80
7	140
8	240
9	>400

Example Activity:

1. Locate the graph of the Kp index for May 27, 2002 (shown above). The website is:
   http://image.gsfc.nasa.gov/poetry/activity/NLightsA.html

2. Read the graph to determine the eight Kp values for that particular day. The eight Kp values are 3, 2, 5, 5, 4, 5, 3, 3

3. Convert the Kp value to an Ap value using the 'Kp Table'. In this case, the converted values are 15, 7, 48, 48, 27, 48, 15, 15

4. Next, average the converted values to obtain the Ap value.
   Ap = (15 + 7 + 48 + 48 + 27 + 48 + 15 + 15) / 8
   Ap = 223/8
   Ap = 27.875 round this to 28.

5. Now that the Ap value has been determined, compare the index with pictures from the IMAGE satellite on the same date. The website is:
   http://image.gsfc.nasa.gov/poetry/activity/NLightsB.html

6. Compare the auroral oval to the Kp index and the Ap value. What does the comparison suggest? Is there a noticeable correlation between the Kp index and the auroral oval seen in the satellite images?

Student Name ________________________________ **Date** _______________

In each of the following problems, locate the Kp graph for the given date, convert the Kp values to an Ap value, and compare those two variables to the IMAGE data for the corresponding dates. Analyze and compare the results for each of the given dates. Summarize the results in a written format. Be sure to include data and reasoning to support your conclusions.

Problem 1 April 19, 2002
Kp graph and IMAGE data:
http://image.gsfc.nasa.gov/poetry/activity/NLights1.html

Problem 2 April 20, 2002
Kp graph and IMAGE data:
http://image.gsfc.nasa.gov/poetry/activity/NLights2.html

Problem 3 July 13, 2000
Kp graph and IMAGE data:
http://image.gsfc.nasa.gov/poetry/activity/NLights3.html

Problem 4 July 14, 2000
Kp graph and IMAGE data:
http://image.gsfc.nasa.gov/poetry/activity/NLights4.html

Problem 5 July 15, 2000
Kp graph and IMAGE data:
http://image.gsfc.nasa.gov/poetry/activity/NLights5.html

Activity 9 Auroral Activity and Latitude

Over the last 100 years, scientists have recognized that there is a relationship between the appearance of the aurora and the amount of disturbance to Earth's magnetic field. As the magnetic field becomes more disturbed, the Northern Lights will be visible the farther south from the Arctic region. By measuring these disturbances, we can predict what the latitude of the southern edge of the Northern Lights will be. This activity lets students use a geographic plot of aurora location and activity, to create their own forecasting relationship for a selected longitude in North America.

Objectives:

Math is essential to science for such purposes as access to outer space, sample collection, measurement, storage, and computation.
Graphs can show a variety of possible relationships between two variables.
Find answers by substituting numerical values in simple algebraic formulas.
Use computers for providing tables and graphs and for making spreadsheet calculations.
Find locations on maps using rectangular and polar coordinates.

Materials:

Graphing calculator
Student page
Calculator instruction pages
Map

Procedures:

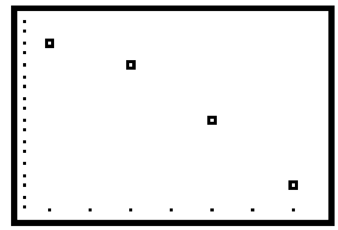
Students apply map reading skills to complete a table of values.
Students graph the table of values and determine a possible correlation between the Kp index and the latitude of the auroral oval.
Students use the graphing calculator (if available) or determine a line of best fit based on the data values.
Students draw the line of best fit.
Students use the line of best fit to determine various latitudes given a specific Kp index value.
Students use the equation for the line of best fit to calculate the latitude for a given Kp value. Students use the equation for the line of best fit to calculate the Kp index when the latitude is given.
Students write a summary of the correlation between the Kp index and the latitude of the auroral oval.

Teacher's Answer Key:

Answer for Question 1

Kp index	Latitude
3	49
5	47
7	42
9	36

Answer for Question 2



Answer for Question 5

Kp index	Latitude
1	49.5
2	49.6
3	49.1
4	48.2
5	46.7
6	44.8
7	42.3
8	39.4
9	35.9

3. Describe the shape of the graph. Is this a linear function? Does a relationship between the Kp index and the auroral oval latitude seem evident?

The shape of the curve looks like half a parabola that opens downward. The relationship appears to be that as the Kp index increases, the latitude decreases. The rate does not appear to be constant.

4.Write an equation for the line or curve of best fit.

$Y = -0.25X^2 + 0.8X + 48.95$

6. What does the entry in column one row two mean?

This entry means that for a Kp index of 2, the auroral latitude is around 49.55 degrees at a particular longitude.

7. Use the above equation to predict the auroral oval latitude when the Kp index is nine.

$Y = -0.25(9)^2 + 0.8(9) + 48.95$

$Y = -20.95 + 7.2 + 48.95$

$Y = 35.2$

The auroral oval latitude is around 35.2 degrees when the Kp index is 9.Answers will vary based on the selected auroral latitude.

8. Predict the Kp index, using the equation of best fit, when the auroral oval latitude is 45 degrees (Hint: use the quadratic formula).

$Y = -0.25X^2 + 0.8X + 48.95$

$45 = -0.25X^2 + .8X + 48.95$

$X = -2.685$ or $X = 5.885$

In this situation, the Kp index would be between 5 and 6. According to the table, the 45 degrees latitude would be between a Kp value of 5 and 6. This is a reasonable prediction.

9. Select another Kp value from the table in problem five, and show how to determine the auroral oval latitude using your equation of best fit.

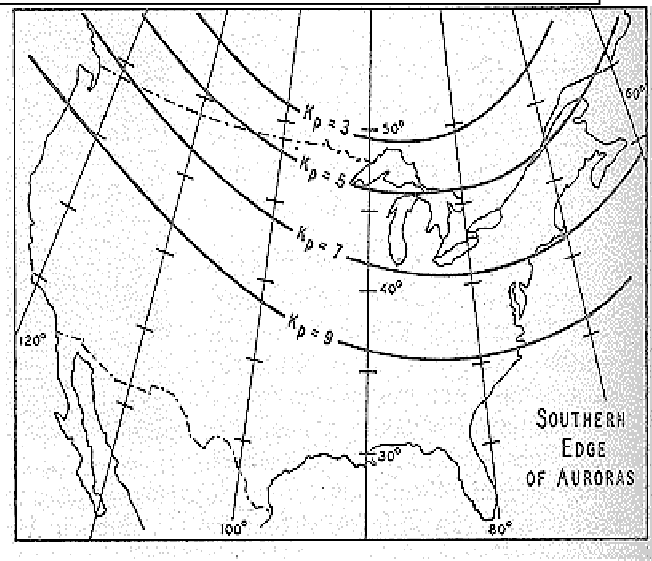
Answers may vary based on the student selection of a Kp value.

10. Select an auroral oval latitude and determine the Kp index.

Hint: problem 8.

Student Name ______________________________ Date ______________

1. From the map on the right, select a longitude, and determine the latitude for each given Kp value. Complete the table below.



Kp index	Auroral Latitude
3	
5	
7	
9	

2. Plot the data values on the graph below. Remember to label the axes!

3. Describe the shape of the graph. Is this a linear function? Does a relationship between the Kp index and the auroral latitude seem evident?

4. Write an equation for the line or curve of best fit.

Student Name ______________________________	Date _______________

5. Complete the table to the right, based on the curve of best fit. Round your answer to the nearest tenth.

Predicted latitude

Kp index	**Latitude**
3	
5	
7	
9	

6. What does the entry in column one row two mean?

7. An equation for the curve of best fit is $Y = -0.25X^2 + 0.8X + 48.95$, where X is the Kp index and y is the auroral oval latitude. Use the equation to predict the auroral latitude when the Kp = 9. Example: For Kp = 3 then X = 3, and $Y = -0.25(3)^2 + 0.8(3) + 48.95 = 49.1$

8. Predict the Kp index, using the equation of best fit, when the auroral oval latitude is 45 degrees (Hint: use the quadratic formula).

9. Select another Kp value from the table in problem five, and show how to determine the auroral oval latitude using your equation of best fit.

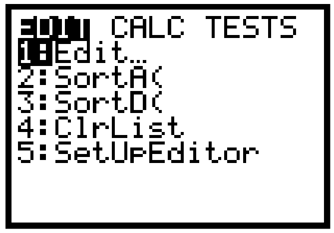
10. Select an auroral latitude and determine the Kp index. (Hint: problem 8)

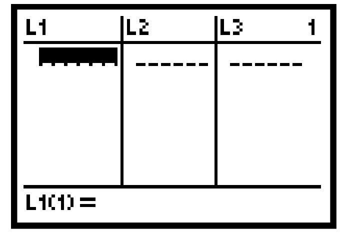
Determining a Line Of Best Fit Using The TI - 83 Graphing Calculator

It is important to note that the keystrokes needed are displayed in boxes and the picture displayed below is what the students should be viewing.

- Enter the data from the table into the calculator. The Kp index will be in List 1 (L1) and the auroral latitude will be in List (L2).

STAT **ENTER**





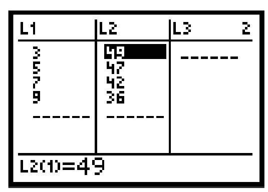
- When entering a data value in List 1, type the data value and press **ENTER**. For example,

3 **ENTER** **5** **ENTER** **7** **ENTER** **9** **ENTER**

- Arrow over to the right to access List 2. Enter List 2's data values by typing the data value and then pressing ENTER for each number.

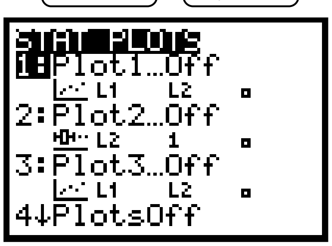
4 **9** **ENTER** **4** **7** **ENTER** **4** **2** **ENTER** **3** **6** **ENTER**

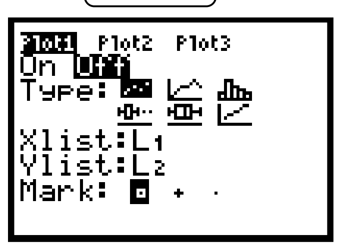
- The completed screen would appear like this:

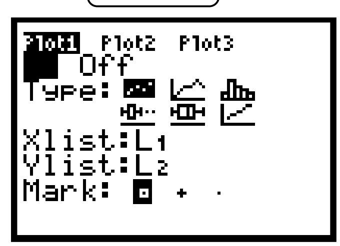


- In order to view the graph, it is necessary to turn on the statistics plot feature on the calculator. Follow these steps.

2nd **y =** **ENTER** **ENTER**



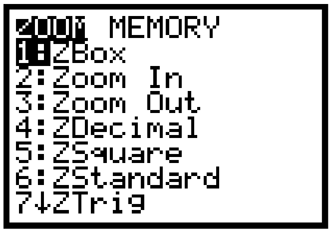


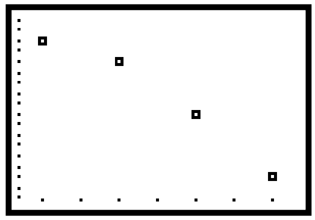


- In order to view the graph, push the **GRAPH** key. **GRAPH**

- The graph may or may not be visible at this point. In order to fit the data to the calculators window, do the following:

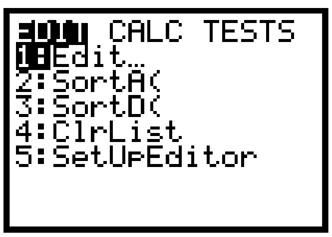
ZOOM **9**

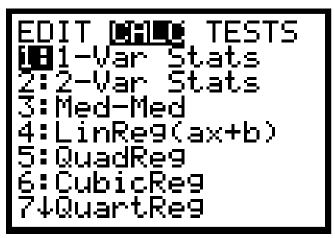


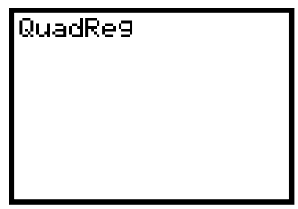


The graph appears to be curved downward, like half of a parabola opening downward. Therefore, a quadratic regression line is necessary.

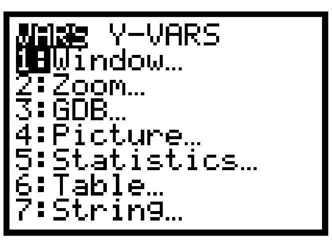
STAT **5**

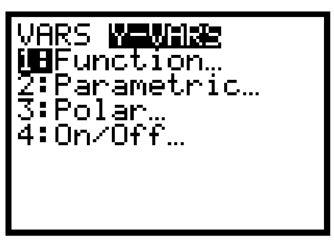




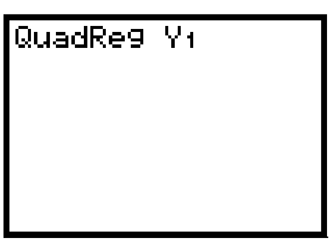


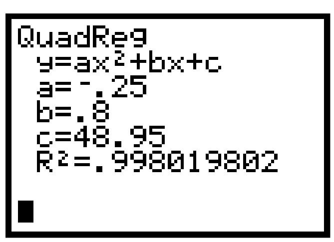
VARS **ENTER**





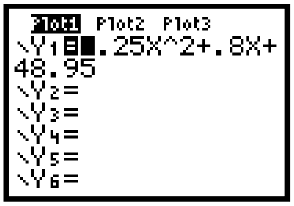
ENTER **ENTER**



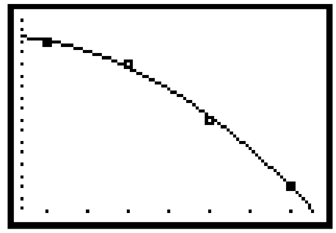


- The screen will display the following information, where a is the quadratic terms coefficient, b is the linear terms coefficient, and c is the constant.

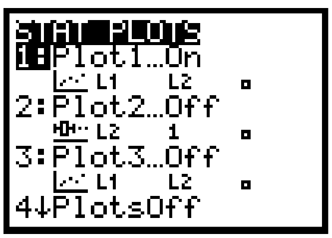
- To view the equation in standard form: **Y =**



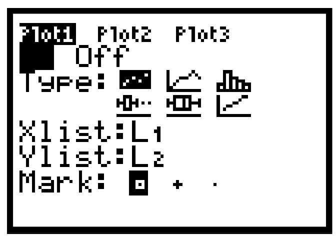
To view the graph, push **GRAPH**



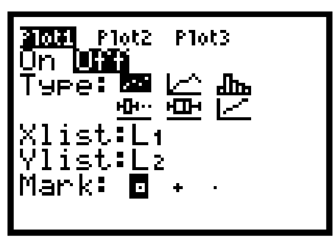
- Next, it would be feasible to use the line to predict the auroral oval latitude using a given Kp index. It is necessary to turn off the stat plots in order to use the regression line. When turning off the plots **2nd** **y =**



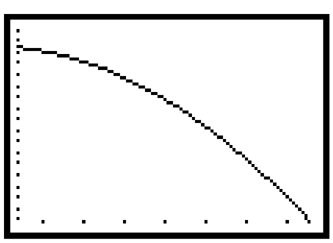
ENTER



- Arrow over so the cursor is over OFF, **ENTER**

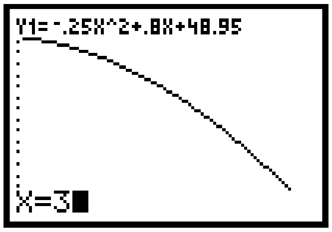


- Go back to the graph **GRAPH**

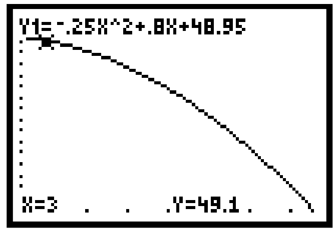


- Press **TRACE** and a blinking cursor will appear on the line. Now use the graph to make predictions. Type in a Kp value such as

TRACE **3**

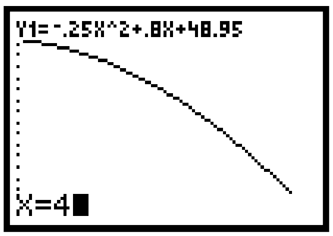


ENTER

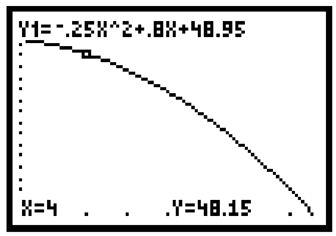


Y = 49.1

4



ENTER

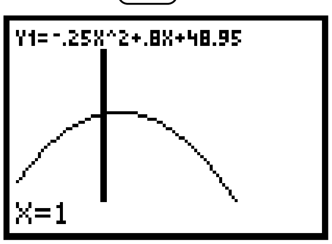


Y = 48.15

- Continue to type in the Kp values up to 9. Record the y values in your table under the Auroral Oval Latitude.

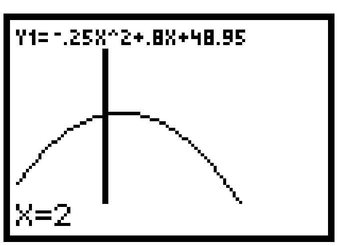
However, when predicting the latitude for a Kp index of a 1 or a 2, the calculator will give you an error message.

1



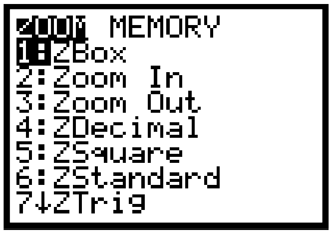
ENTER

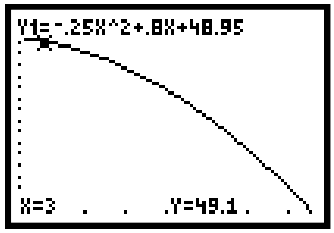
2



This will bring back the graph window the cursor flashing over the entered value. This message indicates that the window range is not appropriate for that value. In order to adjust for these values it is necessary to expand our viewing window.

ZOOM **3** **ENTER**

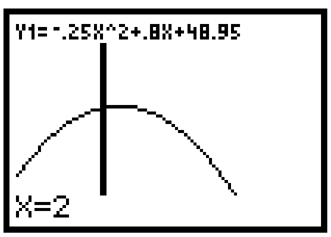


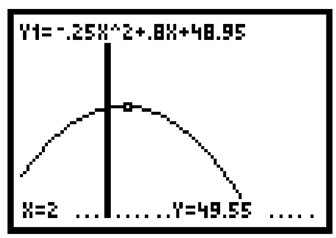


Y = 49.1

The display window will automatically adjust so that the Y-axis is visible.

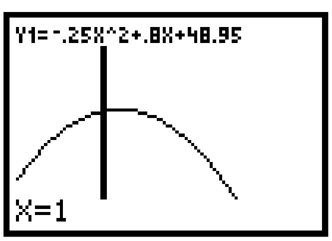
TRACE **2** **ENTER**

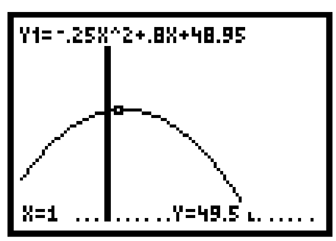




Y = 49.55

1 **ENTER**





Y = 49.5

Activity 10 Decoding An Ancient Mystery

Between 600-1200 AD, the northern people of Scandinavia, called Vikings, had set up a spectacular civilization that was known, and feared, over much of Europe and as far east as Bryzanthium (Constantinople). Their sagas, which told of their many exploits and discoveries, were written using symbols called Runes. The greatest of these saga writers and story tellers was Snorri Sturluson who lived from 1179 to 1241 A.D.

The Vikings knew about the Northern Lights. In their mythology, the colorful auroral archways were identified as the Bifrost Bridge, which was a trembling and fiery path that fallen warriors could travel to Valhalla. The beautiful auroral rays were also imagined to be the lights that were carried by the Valkyries as they rode across the sky in search of Vikings who had been honorably killed in battle. The aurora have also been regarded in ancient folklore as the bringer of harsh weather, or that they are the celestial dance by the souls of dead maidens.

In this activity, students will use the accompanying decoder stone to translate a runic sentence into English. Please note that the sentence is written with English words and is not an authentic Old Icelandic quotation! Some liberty has also been taken with word spellings when no equivalent letters are available (e.g. 'kolor' = color, 'inwisible' = invisible and 'energie' = energy). Also, there was no symbol to represent a question mark.

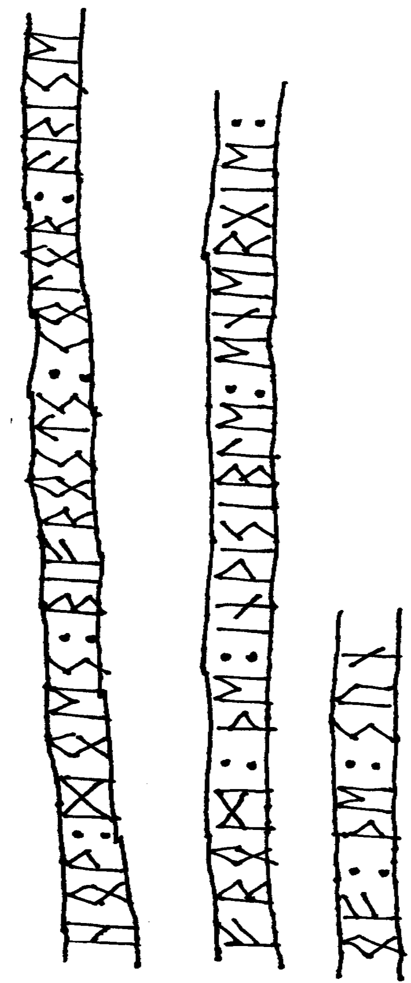
Students will use the alphabet stone (called the Futhark), to assign an English letter to each of the symbols in the string of runes. They will then uncover a message in the form of a question, which they will have to answer. For added difficulty, suggest that the student answer the question in terms that a Viking could understand avoiding anachronistic terms. You may also suggest that the answer be written in Runes. Here is the translation of the Viking's question:

How does Bifrosts kolor arise from the inwisible energie of the sun

To learn more about the history of the Swedish runes, visit:
http://www.tarahill.com/runes/runehist.html

Student Name ____________________________ **Date** ______________

While visiting your Aunt Birgit in Sweden, you happen to be digging in the backyard and uncover a stone with old Viking runes written over it in a spiral. You show it to your Aunt and she looks at it carefully, "Oh, how lucky you are to have found one of those messages from our ancestors!" Your Old Icelandic is pretty rusty, but you use one of your Aunt's books to translate the message on the stone that was inscribed nearly 1200 years ago. Can you answer the Viking's question? Write a short essay that summarizes what you have learned about aurora in this booklet.



Useful Web Resources

Exploratorium "Auroras:Paintings in the Sky"
http://www.exploratorium.edu/learning_studio/auroras/

Archive of aurora photos by Jan Curtis:
http://www.geo.mtu.edu/weather/aurora/images/aurora/jan.curtis/

Archive of aurora photos by Dick Hutchinson:
http://www.ptialaska.net/~hutch/aurora.html

Space Weather Today:
http://www.spaceweather.com/

IMAGE real-time aurora images from space:
http://image.gsfc.nasa.gov/poetry/today/intro.html
http://www.sec.noaa.gov/IMAGE/
http://sprg.ssl.berkeley.edu/image/

NOAA Auroral Activity monitor:
http://www.sec.noaa.gov/pmap/index.html

CANOPUS real-time auroral monitor:
http://www.dan.sp-agency.ca/www/rtoval.htm#TOPOFPAGE

Current solar activity report:
http://www.dxlc.com/solar/

Alaska Science Aurora page for kids:
http://www.alaskascience.com/aurora.htm

Human Impacts of Space Weather:
http://image.gsfc.nasa.gov/poetry/weather01.html

Ask the Space Scientist:
http://image.gsfc.nasa.gov/poetry/ask/askmag.html

More classroom activities:
http://image.gsfc.nasa.gov/poetry/activities.html

The Northern Lights Essay Competition:
http://image.gsfc.nasa.gov/poetry/alaska/alaska.html