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.

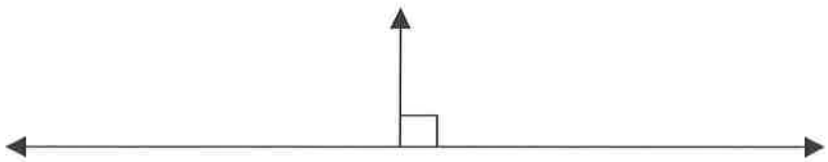
Objective:

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

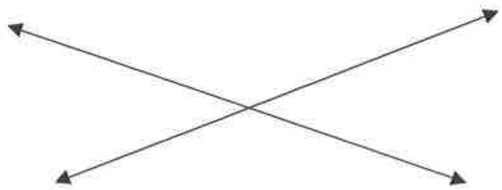
Photograph:
Stormer (left) and an assistant posing with an aurora camera in Bossekop, Norway in 1910.

Vocabulary List:

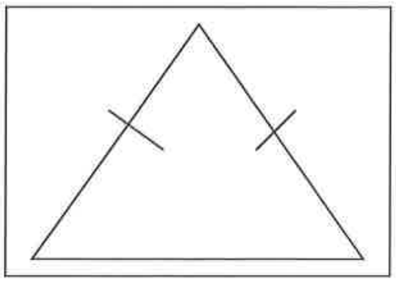
Perpendicular: two lines are perpendicular if the angle between them is 90 degrees.



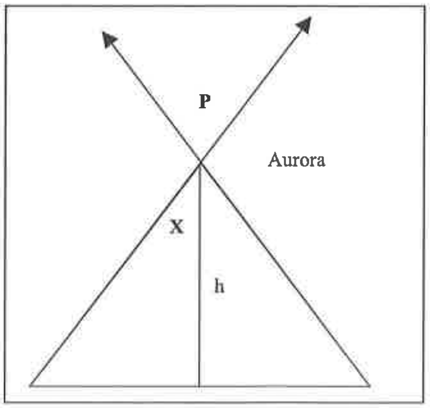
Vertical angles: Angles that share only one point. They are on opposite sides of the transversal.



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.