Lab #55: The Height of Polaris

The size of Earth was unknown for quite some time and has been "discovered" several times and then lost again. To measure it is an easy experiment to do: all it requires is some understanding of the geometry of the sphere.

A similar experiment was performed more than 2,000 years ago (in 240 B.C.) by the Greek astronomer Erathosthenes, working in the Egyptian city of Alexandria. His astronomical measurement came within 2% precision of the modern value, and his main limitation was that in antiquity no precise way existed to measure the distance between two cities, which he needed for comparison.

The astrolabe is an ancient device invented in 150 B.C. by the greatest Greek astronomer Hipparchos on the Island of Rhodes (he is also the founder of trigonometry). It can be used to measure the altitude (height) of stars over the horizon. The picture below is an astrolabe quadrant, dated 1388, now in the British Museum. On the next page you'll find a picture of the simple device you are going to make yourself.

A good way to determine your geographical location is based on the Pole Star in the Little Dipper, Polaris. It is special in that, during the night as Earth spins around, the sky seems to turn around the poles, but Polaris stays in the same location. Once you learn in this lab where it is in the sky, you will always find it in the same place.

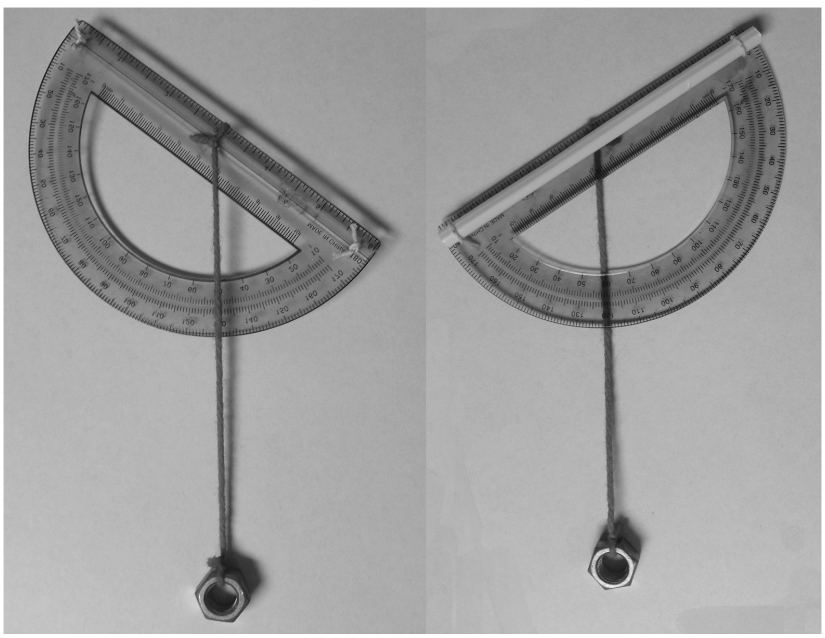
We have asked another class of astronomy in Guatemala to take the same measurement as you will be doing. They said they saw Polaris quite low over the horizon, and their result of the measurement of the height of Polaris was 15^{o}. You may want to know that Guatemala is straight down south of Oxford by 1300 miles. The more South you go, the lower Polaris will be over the horizon.

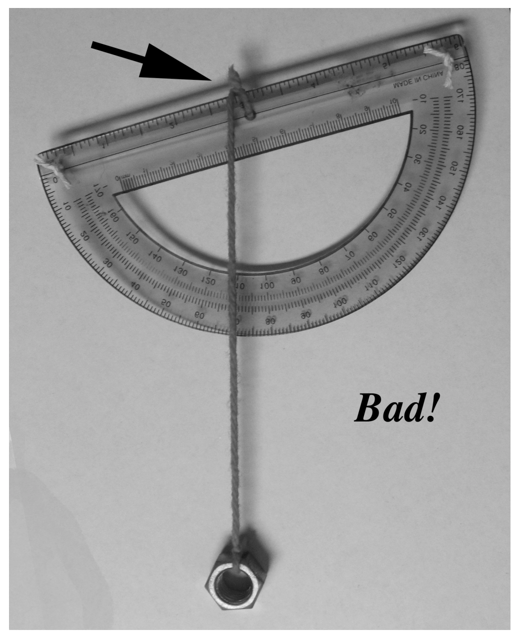
PROCEDURE AND LAB REPORT

Date:_______ Your name: ___________Partner's name: ___________ Section: ___/___

Maximum two students may work together as partners!

1. ***First you need to make your own astrolabe.***
Follow the pictures below. A few pointers come in handy:
The twine will hang down vertically and let you read off the altitude angle of the star you are watching. You will only read the correct angle if the twine pivots around the hole in the protractor, so make sure the knot you tie does not get in the way. (See the "bad" picture.)
The straw must be as long as the side of the protractor, and surely it must be straight, otherwise you cannot look through it. Use scissors to cut it to size.
You want to make sure the string holds the straw secure and it does not come off. **Do not use tape**, because tape sticks to the protractor and cannot be removed without trace!
Use care when making your astrolabe; you'll be awarded credit on proper accuracy.





2. ***Learn how to use the astrolabe.*** For this purpose, aim the straw at a star close to zenith (almost straight up). Look though the straw to see the star. Have your partner read the angle. The angle you find is the distance of the star from zenith, and it should be a small angle like 5° to 15° or something similar. If the reading is not like this, you are reading the wrong scale; you might have to turn the astrolabe around. After this, repeat the exercise with a star low over the horizon; your reading should be an angle just less than 90°. Record your readings:
Star high up: _____°; star low over the horizon: _____°.

3. **Swap with your partner** and repeat these measurements. Your partner's readings:
Star high up: _____°; star low over the horizon: _____°.
(They do not have to be the same; the two of you may even look at different stars.)

4. ***Find Polaris in the sky.*** Ask for your instructor's help if needed.
5. ***Aim the straw at Polaris.*** Look through the hole in the straw and make sure Polaris is visible through the hole and that the twine is hanging down next to the protractor. Have your partner read off the angle the scale says behind the twine. Use a flashlight if necessary. Record your reading for the zenith distance of Polaris: _____^{o}. Now swap with your partner and measure again; the reading is: _____^{o}.
6. ***Interpret your results.*** As you made two measurements of the same value, you'll have to average them. (If you are sure one of the two is incorrect, use only the correct one.) You find that the zenith distance of Polaris is _____^{o}.
   As zenith is obviously always 90^o up, the altitude of Polaris will equal 90^o minus its zenith distance, which you calculate as _____^{o}. This number is your result for the height of Polaris.
7. ***Calculate the size of Earth.*** The difference in the height of Polaris as seen from Oxford and from Guatemala is Δ=___^{o}. Measure the Oxford-Guatemala distance on the map you'll find on the wall of the laboratory; your result is d=________ miles. If Δ degrees are d miles, calculate how many miles will be 360 degrees. Your result is _________ miles, and this is your result for the circumference of the Earth.
8. ***The diameter of the Earth*** will be found if you divide the circumference by π=3.14. Your result is: _________ miles.
9. ***How well does your result compare with the correct value for the diameter of the Earth,*** which is 8,000 miles? Did you do better than Erathosthenes 2250 years ago? ____________
10. ***Have your instructor inspect your astrolabe and record the grade for how carefully it was made.*** Instructor's initials and mark: _________.
11. **Take apart your astrolabe**, put the parts in the boxes, and turn in your report.