Astronomy 101U Skylab #4 – "Road Trip!"

Introduction: Eratosthenes was a Greek scholar in the Egyptian city of Alexandria, the great center of learning of the Mediterranean world in the days of the ascendancy of the Roman Empire. He is credited with having applied simple geometric reasoning to obtain an excellent estimation of the Earth's circumference. With very simple instruments, you can make a similar observation today and measure the Earth's circumference without going all the way around the world.

Equipment: A stick at least one foot long which can be driven into the ground (or a "plumber's helper"), a measuring device (tape measure or ruler), a watch and a way to get somewhere else (car, bus, plane, whatever).

Time Required: Two days when you can make observations of the sun's altitude between 12:15 pm and 1:45 pm Pacific Daylight Time. One of these days should be in Seattle and the other day at least 150 miles north or south of Seattle, say in Portland or Vancouver, B. C. You need not go exactly due north or south, but the experimental results are easier to interpret if you don't wander too far east or west. If necessary, the observations can be made several days apart, but this will require some corrections, so it will be easier to deal with your data if you can do this on consecutive days.

What to Do: Drive your stick (gnomon) into a level, smooth (ideally no grass) piece of ground, making it as close to vertical as possible (a string with a weight can provide a reference). Beginning about 12:15 pm PDT, carefully measure and record the length of the stick's shadow every 10 minutes. Continue this until you are certain that you have observed the shadow at its shortest. Before you remove the stick from the ground, carefully measure the length of that part of the stick above ground. This procedure should be exactly repeated at the other site.

Apply simple trigonometry to convert your measurements of the shadow's length and the gnomon's height to an altitude of the Sun at local noon at your two observation points. If the Sun has changed position in the sky significantly between your observations, you will have to correct for this by determining the declination of the Sun on these two dates. Ask your T.A. for help with this. If you observe on consecutive days, this shouldn't be a big problem.

Measure the difference between the two elevations you measured...this is how much higher (or lower) the Sun is in the sky at your new location. If you know the distance you travelled North or South (read it off a map or your car's odometer if you went straight North or South along I-5, for example, but don't count any East-West distance travelled!), then you can set up a proportionality: The distance you travelled over the Earth's circumference is the same as the angular difference over 360 degrees. Since you know everything except for the circumference, you can solve for that and get your answer for the questions below.

Questions:

(1) Show your work in setting up the proportionality and solving for the Earth's circumference. Watch your significant digits!

(2) List at least five sources of error in this experiment, including numerical estimates of each and how these estimates affect your answer to (1). Also, state how each error could be reduced or eliminated.

(3) Add up your total error from (2) as the square root of the sum of the squares of each error. State the actual value for the circumference of the Earth. Does your value plus or minus the error match the actual value?

(4) You may have noticed that the noon shadow was shorter depending upon how far South you were for each of your measurements. How far South would you have to go on June 21 (the summer solstice) in order to make the noon shadow completely disappear? Explain your answer with a diagram.

(5) How could you prove that this effect is really due to the curvature of the Earth rather than the Sun just being a short distance away from a flat Earth? (This is not easy!)