

PROJECT NOON FINAL REPORT

Modus Operandi: Astronomy professor Dr. Mary Lou West and student William Phillian took shadow measurements using four different sticks over a period of eight days. The measurements were taken on dates before and after the Equinox on March 20, 2003. The actual day of the Equinox was completely cloudy, a fact confirmed by other participating schools located nearby in New Jersey and in the Bronx, N.Y.

We measured the shadow beginning at about five minutes before and after estimated local noon. The shortest shadow measured was selected as representing local noon. Because the lengths of the sticks varied, we calculated the ratio of the shadow length to the stick length in order to ensure the uniformity of our data. The measurements were tabulated along with the corresponding dates by entering them into a spreadsheet. We calculated the sun angles based on our measurements, by using the trigonometric function Arctangent.

Analysis: We used Microsoft Excel® to graph the shadow/stick ratio as a function of the date, which yielded a straight line and its corresponding equation. This line permitted us to interpolate a value of 0.865 for the ratio for March 20. Another graph was done of sun angles as a function of the date, again yielding a straight line and its corresponding equation. This line permitted us to interpolate a value of 40.8 degrees for the sun angle for March 20.

In lieu of formally partnering with other participants in the project, the Project Coordinator, Ihor Charischak, consented to our using their posted data in order to complete our calculations. The Google search engine enabled us to discover a very helpful Internet site that specializes in the calculation of distances using latitude and longitude input. This site, located at www.csgnetwork.com/longlatdistance.html, uses a convenient on-screen calculator. Under the heading of 'Origination', we entered our latitude (40.846 degrees north), and our longitude (74 degrees west). Under the heading 'Destination', we entered the latitude of another participating school as listed in the Noon Day Project Database at www.k12science.org/noonday/asp/updatedata1.asp. Instead of using the listed longitude, we entered our longitude again. Clicking on 'Calculated Distance' resulted in the north/south distance between our locations in kilometers and in statute miles. Keeping the longitude constant enabled the distances to be calculated without the effect of the east/west component. Observations at both places were made at (local) noon, so that there was effectively no east/west component.

We prepared graphs of the sun angle measurements taken by various schools as a function of the latitude of each school for the dates March 18th, 20th and 24th. It can be observed that the sun angle measurements tend to increase nicely with the latitude of the school except for one school. Our work produced a result of 40,763 km for the earth's circumference when we used the data from Marryatville H.S. in Australia to complete our calculations. Varying results were obtained by doing the calculations using the data from several other schools.

Discussion of Errors: The degree of error in the experiment may be calculated by using an accepted value for the circumference, which we calculated using $2\pi r$. The equatorial radius of the earth is given as 6,378 km. (For example, in Bennett, Donahue, Schneider, Voit. *The Essential Cosmic Perspective*. San Francisco: Addison Wesley, 2003), giving a circumference of 40074 km. We calculated the percent error based on this value for

various schools. Possible sources of error in the results may be identified by examining the equation used to calculate the circumference, namely:

$$C = D \times 360 / (A_{\text{School 1}} - A_{\text{School 2}}),$$

where C is the circumference, D is the distance between the two points of measurement and $(A_{\text{School 1}} - A_{\text{School 2}})$ is the difference in the sun angles at schools 1 and 2. Since 360 degrees is a constant, any error must be attributed to one or more of the variables D, $A_{\text{School 1}}$ and $A_{\text{School 2}}$. These include the following possibilities:

- The actual north-south distance between chosen partner schools, not the actual distance “as the crow flies.”
- The accuracy of the measurement of the north-south distance.
- The accuracy of the measurement of the sun angles.
- The difference in sun angles between chosen partner schools.

A graph of percent error as a function of the distance between schools shows that percent error approaches zero for large distances, and is less than 10% for distances greater than 400 km, suggesting that partner schools should be farther rather than closer.

Another graph was prepared in which the average percent error in the circumference was plotted as a function of the type of school (college, high school, middle school). It is observed that the largest errors (17%) are associated with sun angle measurements made by middle schoolers. The errors (6%) are less with high schoolers and even less (1%) with college students.

When the graphs of errors were made, we decided to exclude the results of one school, Alice Deal JHS in Washington, DC. We did this because the difference in our sun angles was so small (0.1 degree), that it produced an erroneously large value for the circumference (720,000 km). If an error had been made of no more than one degree in the sun angle as measured by their school and our school, then the error in the calculated circumference would have been similar to the others.

What we learned:

- That complex problems may be solved by discovering key relationships that can be surprisingly simple.
- That geometry has profound real-life applications beyond even the most commonly cited examples in textbooks.
- That the power of international partnering is invaluable in the process of scientific discovery.
- That the Internet truly is an empowering technology that has vastly improved the way we communicate.
- That Excel is an amazingly powerful tool for categorizing and analyzing data.

With thanks: We thank our Project Coordinator, Ihor Charischak, for his dedication to this important endeavor. Mr. Charischak replied to my several email messages promptly and cheerfully. Thanks also to Stevens Institute for sponsoring this event. Finally, we are grateful to all the other schools that, by their participation, helped to make this project a success.

W.P. & M.L.W.
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