SCOPE

On the skies

Shadows and circumference

On the 22nd of this month, the Sun in its apparent motion along the ecliptic reaches the astronomical coordinates of 0 degrees and 12 hours, a position commonly known as the autumnal equinox. This date marks the beginning of autumn in the northern hemisphere and spring in the southern hemisphere. At noon on this date along the equator, the Sun is directly overhead. For all latitudes, except the poles, the Sun rises directly east and sets directly west and the length of daylight is equal to the length of night.

Information about the position of the Sun, especially its altitude above the horizon, can be used to determine the circumference of the Earth. Eratosthenes, a Greek philosopher and mathematician who lived about 2,000 years ago, was the first person to make this solar-powered calculation. He had read that on a certain date the Sun would be directly overhead in Syene, a city to the south of Alexandria. This interested him because at noon on that date in Alexandria, he cast a shadow that indicated that the Sun was still 7 degrees south of a directly overhead position.

Eratosthenes reasoned that 7 degrees is about 1/50th of a complete circle (360 degrees) and that this would represent the angular distance between Syene and Alexandria. Eratosthenes also knew the ground distance between the two cities. This allowed him to roughly estimate the entire circumference of the Earth by simply multiplying the distance between the two cities by 50.

Students can re-create Eratosthenes' experiment by teaming up with a school on the same line of longitude as their own school, but at a different latitude. Information can be shared across the Internet or phone lines. (See Figure 1 for a list of web sites that can put you in touch with a partner school.) The experiment is done by measuring the midday angle of the Sun at each location and calculating the difference between the two (see Figure 2). The ground distance in kilometers between the two locations needs to be determined as well (1 degree of latitude equals 110.2 km). The following formula can then be used to determine the Earth's circumference:

distance between schools
x (360°/angle difference)
= Earth's circumference

Students can also re-create Eratosthenes' measurement without a partner class on either of the two Equinox dates (September 22, 1997 and March 20, 1998). On those dates, the Sun will be directly overhead at the equator with an altitude of 90 degrees above the horizon. Students can use the altitude of the midday Sun in their own town to determine their home latitude, (90° – Sun's midday altitude = latitude), and then multiply the latitude by 110.2 km to calculate their distance from the equator. These numbers can then be plugged into the formula for calculating the Earth's circumference.

Measurements made using this method are actually determining the polar circumference (39,678 km) of the Earth, which is slightly less than the equatorial circumference (40,008 km). Have students compare their results with the Earth's actual circumference to determine the percent error in their approximations.

Figure 1. Web sites for the Eratosthenes project

The Noon Project
http://www.ed.uiuc.edu/courses/satex/sp96/noon-project

Brian Poelker Midwest Central Middle School
bpoelker@mail.isbe.state.il.us

Geographic Distances
http://www.ngdc.noaa.gov

Evening planets

Venus: Very low over northwestern horizon and sets about one hour after sunset
Mars: Low over western horizon and sets about two hours after sunset
Jupiter: Over southeastern horizon at sunset
Saturn: Rises at about sunset and visible all night

Moon phases

September
New Moon - September 1
First Quarter - September 10
Full Moon - September 16
Last Quarter - September 23

October
New Moon - October 1
First Quarter - October 9
Full Moon - October 16
Last Quarter - October 23
New Moon - October 31

Bob Riddle is the Planetarium Director of the Kansas City School District at Southwest Science & Math Magnet High School. E-mail: starwalk@gvi.net. QueTal astronomy homepage: http://currentsky.com

Figure 2. Calculating the Sun's altitude above the horizon