Name_____ **Section**_____

Partner(s)_____ **Date**_____

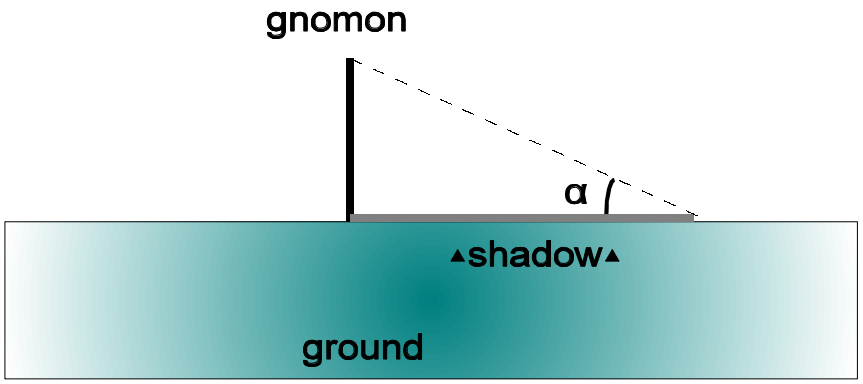
DETERMINING SOLAR ALTITUDE USING THE GNOMON

Does the Sun ever occur directly overhead in Maryland? If it does, how would you determine or know it was directly overhead?

How does the altitude change during the day or from day to day?

The altitude of the Sun is the angle the Sun is above the horizon, your horizontal viewing surface. The solar altitude is zero at sunrise and sunset. To determine the altitude of the Sun, we can use an ancient astronomical measuring device known as a gnomon, which is a vertical stick set in the ground that casts a shadow. The gnomon is illustrated in the diagram below. The altitude, or the angle labelled á, can be measured with a protractor by placing a peg at the end of the shadow and holding a string from the top of the gnomon to the peg forming a triangle, or it can be calculated from the tangent of á.

Sun



The gnomon was invented in the sixth century B.C. by Anaximenes of Miletus, an early Greek philosopher. Its early use was for time-keeping.

This activity explores the use of the gnomon to determine the altitude of the Sun.

HOW ARE ALTITUDE AND SHADOW LENGTH RELATED?

You will need a small vertical object (pencil in sewing thread spool, crayon in clay ball, or a small bathroom plunger) and a bright flashlight. Lay the flashlight on the table (your horizon) and shine it at the vertical object. This is sunrise (or sunset).

What is the shadow length?

Now slowly increase the angle of the flashlight with the table, always pointing the flashlight at the vertical object. As the angle or altitude increases, what happens to shadow length?

Hold the flashlight directly over the vertical object. What is the shadow length? From sunrise to sunset, how does altitude and shadow length vary? Sketch a graph.

Get a straight pole or stick about 1 meter long. A 1.25 cm diameter dowel is convenient. Place the stick in the ground so that it is vertical and will remain at a constant height. Measure the height (H) of the stick. If you must remove the stick place a mark on the stick so that it can be put in the ground to the same depth. This low-technology device is known as a gnomon. Any vertical object can become a gnomon.

HOW DOES THE SUN'S ALTITUDE CHANGE DURING THE DAY?

Place the gnomon in a sunny, open area. Observe the shadow length during the day (every half-hour or hour) and mark each position with a wooden peg labelled with the time. Place a string from the top of the gnomon to the end of the shadow (peg). Using a protractor measure (see illustration below) the Sun's altitude or angle above the horizon. Also measure the shadow length, L (gnomon to peg distance). Plot a graph of altitude versus time.

How does altitude vary with time?

When is the Sun highest in the sky?

How do altitude and shadow length vary?

DATA FROM SUMMER AND WINTER

Using the data collected with a gnomon on 15 January and 8 August 1995:

< Plot a graph containing both winter and summer data of shadow length vs. time.

< Plot a graph containing both winter and summer data of altitude vs. time.

Plot time on the x-axis for both plots. Start the time scale at 6:00 am.

	WINTER		SUMMER	
Time	Shadow Length	Altitude	Shadow Length	Altitude
8:30 am	475 cm	10.6E	179 cm	24.9E
9:00 am	341	14.6	147	29.5
9:30 am	264	18.6	118	35.1
10:00 am	20	22.0	98	40.3
10:30 am	190	25.1	79	46.4
11:00 am	174	27.1	69	50.3
11:30 am	159	29.2	56	56.0
12:00 pm	-	-	46	61.0
12:30 pm	153	30.2	41	63.7
1:00 pm	156	29.7	37.5	65.7
1:30 pm	-	-	37.5	65.7
2:00 pm	177	26.7	39	64.8
2:30 pm	-	-	45	61.5
3:00 pm	-	-	63	52.8

From the graphs, determine the maximum altitude and when it occurs for the two dates.

Date	Maximum Altitude	Time
15 January 1995		
8 August 1995		

Using the table at the end of this activity, how close do the data come to the maximum and minimum values for Maryland's latitude?

For the early morning data on the altitude graph, extend the lines back to zero altitude and predict the approximate time of sunrise on each date.

Determine the length of daylight hours for each day. Describe how you determined.

The state of Maryland falls between 37E 53' N to 39E 43' N latitude. If an average latitude of 39EN is assumed, the maximum and minimum solar altitudes for Maryland can be calculated. These are given in the table below.

Time of Year	Solar Altitude	Event	Earth-Sun Relationship
21-23 June	74.5E (maximum)	Summer Solstice	Sun overhead at 23.5EN latitude
21-23 September 21-23 March	51.0E	Fall Equinox Spring Equinox	Sun overhead at equator
21-23 December	27.5E (minimum)	Winter Solstice	Sun overhead at 23.5ES latitude

The Sun never shines directly overhead (á = 90E) in Maryland! Vertical objects will always cast shadows on sunny days. Only between 23.5EN to 23.5ES latitude will the Sun occur directly overhead. The annual cycling of solar altitude is directly related to the Earth's seasons.