Name(s) ____________________ Section Time ___________

ASTRONOMY 25 SUMMER 2017

PROJECT 2: THE HEIGHT OF THE SUN

Rules: 1) Do the project by yourself or with one other person. If you want to work with a partner, get an agreement form from the instructor and turn it in next week.

2) Bring your project to class every Monday to be stamped and checked.

NO STAMPS, NO CREDIT.

3) Turn in your completed project on or before the due date **July 20.**

Purpose: The purpose of this project is to find out whether the Sun at noon is always the same height in the sky.

Overview: You will observe the Sun at noon once a week for four weeks. You will be measuring the angle between the Sun and the horizon, the Sun's **altitude.**

Equipment: You will need a yardstick, meter stick, or tape measure. You will also need a watch or a cellphone.

Preparation: Find a stick or pole, about 2 or 3 feet high, that is stuck in the ground. A suitable pole is vertical (straight up and down), has a narrow point, is in sunlight at noon, and casts a shadow onto flat ground. You are going to measure length of the shadow of the pole. Use a plumb bob to make sure the pole is vertical. (A plumb bob is just a weight hanging from the end of a string.)

Make all your measurements to the nearest 1/8 inch. If you think the measurement is an even number of inches, write the eighths as 0/8. For example, if your pole is exactly 40 inches tall, write it is 40 0/8 inch. That tells me you measured to the nearest eighth of an inch. (If you prefer, you can measure in millimeters, which will make your calculations easier. DON'T convert inches to millimeters if you measure in inches.) Estimate the error in all your measurements.

<u>Example</u>:

Your pole is between 39 7/8 and 40 1/8 inches in height.

Record the height as 40 0/8 ± 1/8 inch.

(Q1) How high is your pole (to the nearest 1/8 inch or mm)?

(Q1a) If you are using inches and feet, convert to tenths of an inch.

Example: 5 ' 10 1/4 inch = 5x12 inches + 10.25 inches = 70.25 inches = 70.3 inches

Hypothesis: What do you think will happen to the length of the shadow over the next four weeks? The length of the shadow tells you the height (altitude) of the Sun. The longer the shadow, the lower the Sun is in the sky.

(Q2) Predict how the height of the Sun will change, or predict that it will stay the same. If you think it will change, will it get higher or lower?

Over the period of the experiment, the height of the Sun will...

Procedure: Observe the Sun at noon once a week. To get the most accurate time, check the time on your cellphone or watch against the official time at www.time.gov.

True noon is when the Sun is highest in the sky, that is, when it crosses the meridian. This will not be exactly at 12:00 for various reasons. For one thing, we are located 7 minutes to the east of longitude 120°, the standard longitude for the Pacific time zone. That means that the Sun crosses the meridian here 7 minutes earlier than it does at longitude 120°. So in the winter, noon occurs about 11:53 PST. In the summer, clocks are moved an hour forward, so noon occurs about 12:53 PDT.

The precise time of true noon varies over the course of the year as the Sun moves north and south and speeds up and slows down. Depending on the time of year, noon can occur about 15 minutes earlier or later. So you will have to observe over a 20 minute period to determine the precise time of true noon; that is, the moment when the Sun is highest in the sky. That will be when the shadow is the shortest. Keep observing until the shadow starts getting longer. Probably the shadow will be the same length for several minutes in a row. Pick the middle time during that period and record it as "Time of shortest shadow."

YOU NEED TO SEE THE SHADOW GETTING SHORTER AND THEN LONGER AGAIN. If the shadow is already getting longer when you start observing, you need to start at an earlier time. If the shadow is still getting shorter at 1:00, you need to keep going until it starts getting longer.

Measure the length of the shadow at the exact time and estimate the uncertainty (for example, ± 1/4 inch). Measure to the nearest 1/8 inch (or the nearest millimeter). If your measurement is an even number of inches, write the eighths as "0/8" to show that you measured to the nearest eighth of an inch. Example: 18 0/8 ± 1/4 inch. Move the yardstick along as the shadow moves.

If it is cloudy, come back another day.

Show your project to the instructor every week to be checked.

Observations.
Record your data on the following two pages.

When you are done, summarize your shortest-shadow times in the following table.

DATE	PDT	PST	LMT

PST (Pacific Standard Time) is one hour **earlier** than PDT (Pacific Daylight Time).

LMT (Local Mean Time) is the true local time. LMT is 7 minutes **later** than PST.
True noon is 12:00 LMT.

Week #1: Date _______________

Height of pole ______________

Length of shortest shadow ________________±______ inches/mm

Convert to tenths of inches (if using inches)________________±______ in.

Time of shortest shadow ________________

TIME (PDT)	**LENGTH OF SHADOW**	**TIME (PDT)**	**LENGTH OF SHADOW**
12:51		1:01	
12:52		1:02	
12:53		1:03	
12:54		1:04	
12:55		1:05	
12:56		1:06	
12:57		1:07	
12:58		1:08	
12:59		1:09	
1:00		1:10	

Week #2: Date _______________

Height of pole ______________

Length of shortest shadow ________________±______ inches/mm

Convert to tenths of inches (if using inches)________________±______ in.

Time of shortest shadow ________________

TIME (PDT)	**LENGTH OF SHADOW**	**TIME (PDT)**	**LENGTH OF SHADOW**
12:51		1:01	
12:52		1:02	
12:53		1:03	
12:54		1:04	
12:55		1:05	
12:56		1:06	
12:57		1:07	
12:58		1:08	
12:59		1:09	
1:00		1:10	

Week #3: Date ________________

Height of pole _______________

Length of shortest shadow _________________±_______ inches/mm

Convert to tenths of inches (if using inches)_________________±_______ in.

Time of shortest shadow _________________

TIME (PDT)	**LENGTH OF SHADOW**	**TIME (PDT)**	**LENGTH OF SHADOW**
12:51		1:01	
12:52		1:02	
12:53		1:03	
12:54		1:04	
12:55		1:05	
12:56		1:06	
12:57		1:07	
12:58		1:08	
12:59		1:09	
1:00		1:10	

Week #4: Date ________________

Height of pole _______________

Length of shortest shadow _________________±_______ inches/mm

Convert to tenths of inches (if using inches)_________________±_______ in.

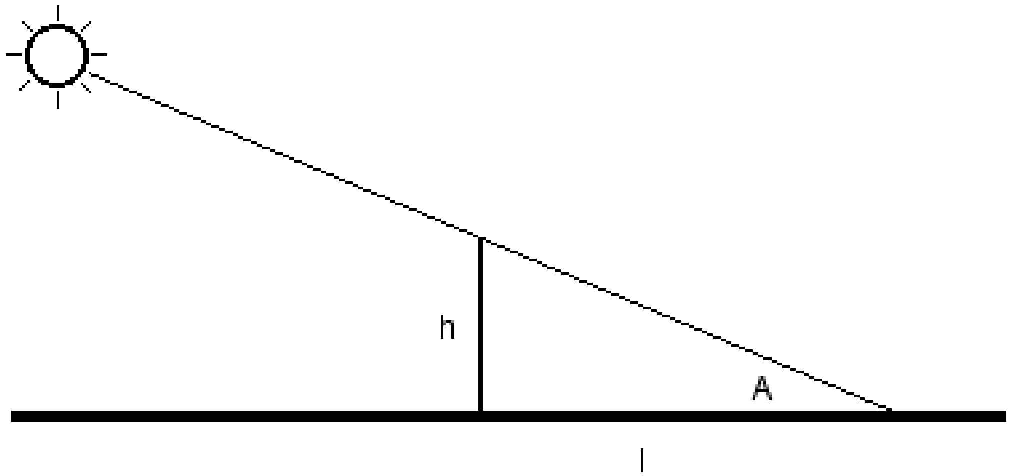
Time of shortest shadow _________________

TIME (PDT)	**LENGTH OF SHADOW**	**TIME (PDT)**	**LENGTH OF SHADOW**
12:51		1:01	
12:52		1:02	
12:53		1:03	
12:54		1:04	
12:55		1:05	
12:56		1:06	
12:57		1:07	
12:58		1:08	
12:59		1:09	
1:00		1:10	

Analysis

Record the **times** of shortest shadow in the table on page 2.

Calculate the altitude of the Sun. The **altitude** of the Sun is the angle between the horizon and the Sun, angle A in the diagram.



What you have measured is the length of the shadow, *l.* In order to calculate the angle A, we need to do some elementary trigonometry. Trigonometry tells us that the tangent of the angle A is the ratio of *h* to *l:*

$$\tan(A) = \frac{h}{l}$$

Here *h* is the height of the pole.
To solve for A, you need to take the *inverse tangent,* arctan:

$$A = \arctan\left(\frac{h}{l}\right) = \tan^{-1}\left(\frac{h}{l}\right)$$

On many calculators, such is the TI30-Xa, the function arctan is labeled **tan**$^{-1}$. To find A, you just calculate *h/l* and then hit the yellow key and then the **tan** key. For example, if *h/l* = 0.5, then A = atan(0.5) = 26.56°. Try this example on your calculator to make sure you get the right answer.

Warning: if your calculator displays the word "RAD" in the screen, it is set to show angles in radians rather than degrees. In this example, the calculator will read 0.4636 instead of 26.56. If it says "GRAD," it is reading in grads. If using the TI30-Xa or similar calculator, hit the DEG button until the screen displays DEG at the top.

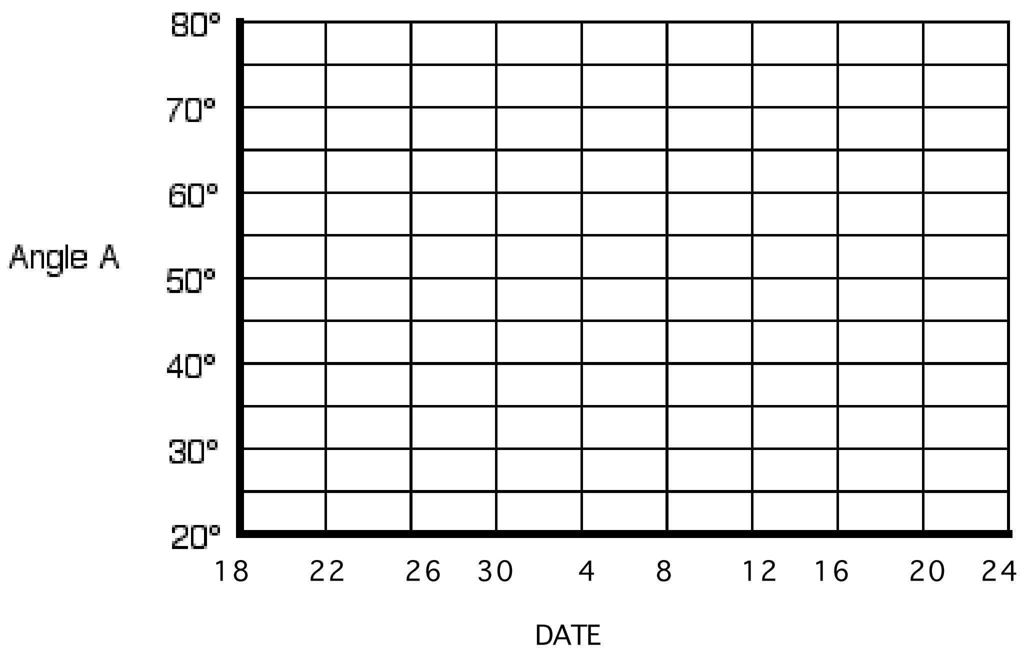
If you don't have a calculator with the tangent function, there is a table of tangents on my website.

Record the results of your calculations in the table on the next page.

Record your data and calculations in the table. If using inches, enter the pole height and shadow length in decimal inches (not fractions). Make sure you calculate *h/l* and not *l/h.* Make sure the altitude is between 0° and 90°. Round off to the nearest degree.

DATE	TIME	POLE HEIGHT *(h)*	SHADOW LENGTH (*l*)	*h/l*	SUN ALTI-TUDE (A)

Plot the angle versus the date. Plot a dot for each observation. Draw a straight line on the graph in such a way that the dots are as close as possible to the straight line.



(Q3) Are your values of the Sun's altitude reasonable? They can't be greater than 80° or less than 35° in southern California. If not, re-check your calculations.

(Q4) Do the points seem like they fall on a straight line?

(Q5) Calculate the slope of the line. This is the number of degrees per day that the Sun's altitude changes this time of year. (See instructions on the downloads page on sabik.org.) **Calculate the slope of the line, not the data points. Show your calculations.**

Wrap-up

Answer after you do your analysis.

(Q6) Discuss the sources of error in your length measurements, that is, what effects might have made your measurements a bit off?

(Q7) Did you observations confirm your hypothesis regarding the height of the noon Sun? If not, what is your new hypothesis?

(Q8) Did the time of true solar noon (the time of shortest shadow) change during the course of your project? If so, how much did it change? Earlier or later?

(Q9) Write a paragraph about how the Sun's height changed (or didn't change) during this project?. How much did it change from week to week? Was the **change** in the last week greater or less than the change in the first week? Be sure to write complete sentences.