Union College Spring 2016

**Astronomy 50 Lab: Apparent Motion of the Sun**

The apparent motion of the Sun throughout the year was one of the first and most important astronomical observations made by humanity. Archeoastronomy structures like Stonehenge and Machu Picchu are designed largely around the position of the Sun at certain times of the year. This helped the people know when it was time to plant the crops, for example. In this lab, you will chart the changing position of the Sun over the next month.

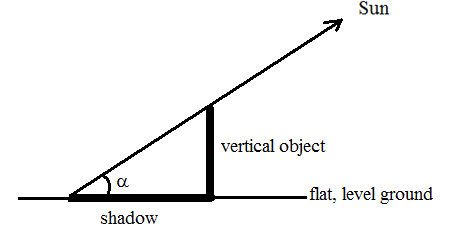
There are two ways of measuring the motion of the Sun, relative to the ground. You should make both measurements.

A. Measure the elevation angle of the Sun at true noon. This is, essentially, measuring the highest in the sky that the Sun gets during the day. By “true noon” we mean, specifically, when the Sun is highest in the sky (not when our clocks say 12:00). Let’s first discuss measuring the Sun’s elevation angle, and then we’ll address the issue of getting this at true noon.

A simple and fairly accurate method to obtain the elevation angle of the Sun is to measure the length of the shadow of a vertical object. Consider Figure 1, below. Provided that **the object casting the shadow is vertical** and that **the ground is horizontal**, then the shadow caster, shadow, and line to the Sun make a right triangle. The elevation angle of the Sun, labeled , then is equal to the inverse tangent of the height of the object divided by the length of the shadow,

 = tan-1(H/L),

where H is the height of the shadow caster and L is the length of its shadow.



**Figure 1. Elevation angle, , of the Sun and length of a shadow.**

Now how do we know when it is "true noon?" This is not when your watch says exactly 12:00; your watch time is not exactly the same as Solar time, which is what determines true noon. The time on your watch is set by your time zone, and so all cities in the same time zone will have noon at the same time, but because time zones are one hour wide, the time of true noon will vary by as much as one hour across the time zone. Additionally, when we are in Daylight Savings time, we shifted our clocks by an hour, while the Sun, of course, did not shift. (There is another subtle effect, which you don’t need to know. This is that because of the slight ellipticity of the Earth’s orbit, the exact moment of true noon varies a little bit throughout the year, by as much as 20 minutes. If you are curious about this effect and would like me to explain it to you, feel free to ask.) The easiest and most accurate approach that you can use is the following.

Since the Sun is highest in the sky at true noon, this will be when the shadow is shortest. So, you can measure the shadow length every five minutes for about a half-hour bracketing the time of expected true noon (check the sunrise and set times for Schenectady on line and determine the time that is exactly half-way between) and then determine the minimum shadow length by plotting shadow length vs. time and either drawing a *smooth* curve through the points (don't connect the dots), or using Excel to fit a parabola. From the graph, read the shortest shadow length for the curve you drew. The more frequently you measure the shadow the better. You'll need data about every five minutes. The accuracy of your result is improved by making use of more data points.

Use this method to determine the angle of the Sun’s rays relative to the ground for the next four weeks. Note: it is important and worth the effort to make sure that the ground is horizontal and the shadow caster is vertical – you can use a level for this. **Make measurements two days per week**.

B. Position of the Sun on horizon. Find a convenient location where you can see to the West to observe the setting Sun. Sketch the horizon, as seen from this spot, as carefully as you can—be extra careful to draw it to scale. **Two times per week for the next month**, as sunset approaches, go to this exact same spot and note both the position of the setting Sun relative to the horizon and the exact time of sunset.

**Analysis**: At the end of the month, you can analyze your data as follows.

1. Make a graph with the Sun’s elevation angle on the y-axis and date on the x-axis. In what way (increase, decrease, or stay the same) does the Sun’s elevation angle change as we approach summer?

2. In lab session (at the end of the month), use the provided equipment -- a protractor, and an array of nails, and a square wire loop -- to model the Sun rays (the nails) and the ground (the square loop) at the beginning of the month and at the end. Count the number of nails that pass through the loop at the beginning and at the end and calculate the ratio:

R1=(Number of nails passing through at end)/ (Number of nails passing through at start).

If this demo doesn’t work, instead do:

R1=SIN(alpha\_max (at end of lab)) / SIN(alpha\_max (at start of lab)).

Since the Sun’s rays carry energy and heat the ground, this ratio also equals the ratio of the heating rate of the ground at the end and at the beginning of the month. What is this ratio as inferred by your data?

3. Examine the motion of the Sun along the Western horizon and comment on how one can use the position of the setting or rising Sun on the horizon to predict the seasons.

4. Make a graph with sunset time on the y-axis and date on the x-axis. Does the graph show that the days are getting longer, shorter, or stay the same?

5. In lab, using the globe and flashlight, and your conclusion from analysis step 1 about the height of the Sun vs. date, turn the globe for the different positions of the flashlight and note the difference in the fraction of the day that the ground is in light and what fraction it is in dark. Calculate the time difference in the sunsets at the beginning and at the end of the month. Assuming that there is a similar shift in sunrise (but in the opposite sense, so that later sunset corresponds with earlier sunrise), to calculate the ratio:

R2 = (Number of minutes of daylight at end)/(Number of minutes at start).

This ratio represents the length of heating time for the ground. (During the night time the ground cools off by radiating away infrared light…except for the radiation blocked by the greenhouse gases in the atmosphere.) What is this ratio according to your data?

6. Consider the *product* of the ratios you calculated in 2 and 5, i.e. R1 x R2. This is, roughly, a measure of the ratio of the *total* amount of heat the ground receives per day at the end of the month vs. at the start.

**Questions to Answer for Discussion:**

1. Consider your calculated ratios of rate of heating, number of minutes of heating, and the product of the two and explain how this explains the seasons. Note that your measurements occurred over a period of only a month – from the start of April ti the start of May, and imagine how much greater this ratio in total heat received would be if you could make and compare these measurements in December and June.

2. Use your observations to explain what structures like Stonehenge are really about why so many ancient societies went to the trouble of making such structures.

**Table 1:  vs. time on each day**

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