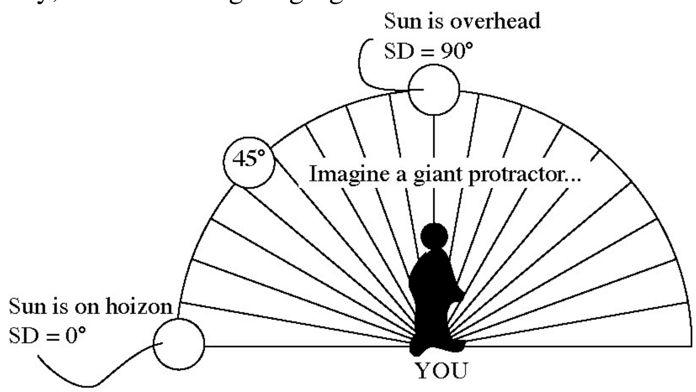
LAB 3: THE SUN AND CLIMATE

NAME:
LAB PARTNER(S):

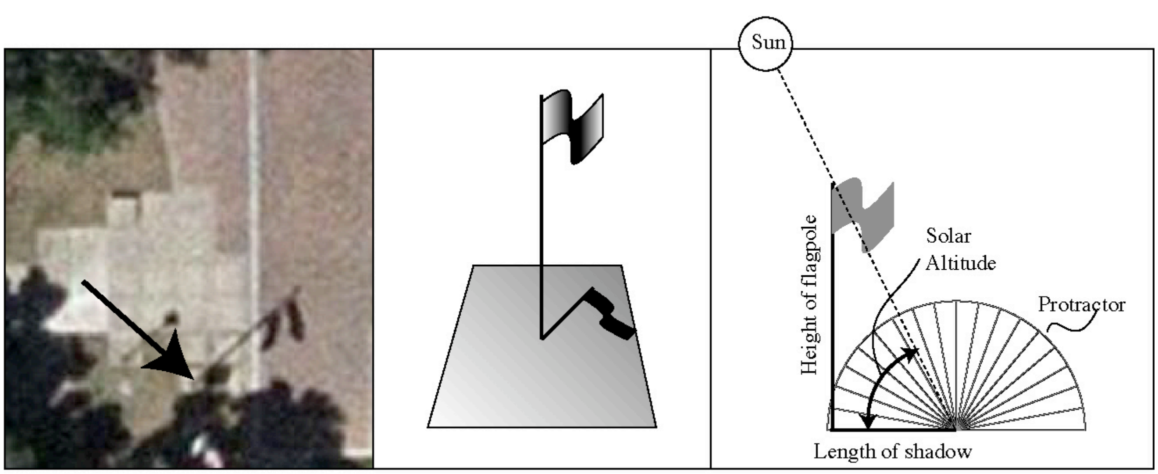
*The main objective of today's lab is for you to be able to visualize the sun's position above the horizon (**altitude**) as it changes through the seasons, and to relate that to the **solar declination**, the latitude where the sun is directly overhead at noon. You'll also get some experience with a marine sextant, a valuable tool if you are ever to become a pirate and sail the high seas.*

You probably already know that, from our perspective on Earth, the sun appears to rise in the east, travel in an arc across the sky, and set in the west. If you are so lucky as to watch its progress across the sky from the beach during a hot July day, you will notice that it gets to be very nearly overhead at noon, and makes a "green flash" over the water just before it dips below the horizon in the evening.

The sun's position in the sky is measured using an angle measurement called the **solar altitude**. Imagine a giant protractor sitting with 0° on the horizon and 90° above your head. The sun's "position" on this diagram is its altitude. Everybody (hopefully) knows that the sun isn't *really* traveling across the sky, but we're imagining right now…



In front of the B building (Park Boulevard side) is a flagpole. You can use this flagpole and its shadow as an indicator of the sun's altitude. Consider how different the flagpole's shadow would be at noon versus late in the afternoon.



Exercises

1. What information would you need about the flagpole and its shadow in order to draw a scale drawing (similar to the one in the box on the right, above)?
2. Go outside and measure the flagpole's shadow using the tape measure. Record your measurement in today's field notes. *Remember: the tape measure measures in feet and inches, but you will need to use metric measurements here. Be sure to write the* ***original*** *measurement as well as any conversions here. 1 in = 2.54 cm.*

3. Carefully draw the flagpole and its shadow using a scale of 1:150 (1 cm on the drawing corresponds to 1.5 m in real life) in your field notebook. Label the flagpole, shadow, and solar altitude.
4. Measure the solar altitude using a protractor, and write it on your drawing.
5. On the drawing from #3, draw (to scale) shadows of the following lengths. Measure the solar altitude for each shadow.

Shadow Length = SL (m)	Flagpole Height = FH (m)	FH/SL	Solar Altitude (°)
0.50	9.14	18.3	
1.00	9.14	9.14	
3.00	9.14	3.05	
9.00	9.14	1.02	
15.00	9.14	0.61	

6. Also in your field notebook, graph the sun's altitude versus the "FH/SL" value above. *FYI: If you fit a smooth curve to this relationship, it would be the* ***tangent*** *function that you may or may not know from trigonometry:*

$$\left(\frac{FH}{SL}\right) = \tan(SA)$$

or…

$$\tan^{-1}\left(\frac{FH}{SL}\right) = (SA)$$

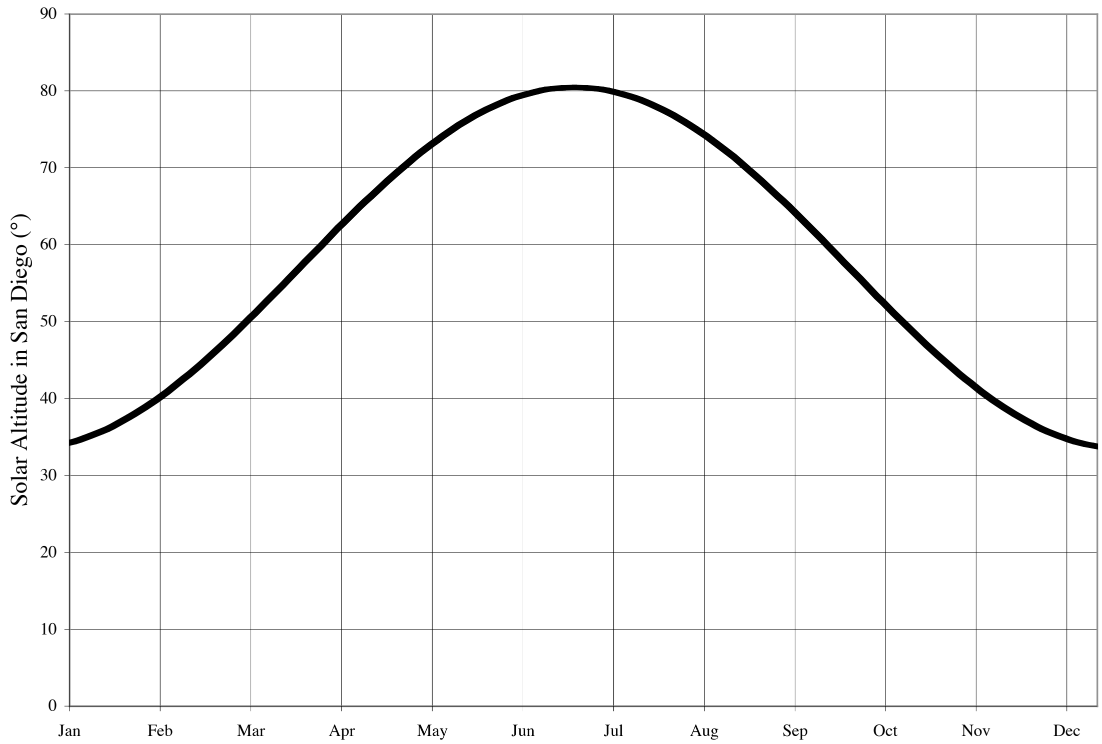
You can measure the sun's declination more easily with a **marine sextant**, which you've probably seen in movie where people say things like "avast, ye mateys" and "scurvy." The sextant has a set of mirrors that you can maneuver so that the image of the sun's disc coincides with the image of the horizon. This allows you the measure the angle of the sun above the horizon very precisely.

Exercises

7. Good scientific note-taking always includes *metadata*, or information about *how* you took your measurements. Let's say you were a scientist trying to determine the relationship between the sun's position in the sky and the local air temperature in San Diego throughout the course of the year. Brainstorm with your teammates for a few minutes to decide what information *besides* solar altitude you will need to record. In your field notes, make a table like the one on p. 6 (labeled SOLAR ALTITUDE NOTES). In each row of the table, write down a list of questions that you will need to answer for each measurement. I have provided two questions as examples.

8. Using the sextant, measure the sun's altitude and write it in the table in your notebook. Also record the other appropriate information. Remember **always** to record your units of measurement! *We will return to this experiment later in the year*.

As you should know by now, the sun's altitude changes with the seasons. I've plotted the solar altitude at local solar noon (not *exactly* 12:00 noon on your watch…) over the course of a year on a graph below:



Exercises

9. Draw a mark on the graph above that corresponds to your solar altitude measurement from #8. In your field notebook, explain the following: Does your mark exactly match the thick line on the graph above? If not, why not? Be as specific as possible in your answer. *"Human error" is* ***not*** *an appropriate answer!*

10. Remember the flagpole's shadow that you measured in question #2? What time of year will the flagpole's shadow be shortest? Is there ever a time of year where the flagpole has *no* shadow at all? Determine the length of the flagpole's shadow *at its shortest* using the graphs and/or equations from #6. *Show all of your work in your field notes, and remember to write down the units of measurement!*

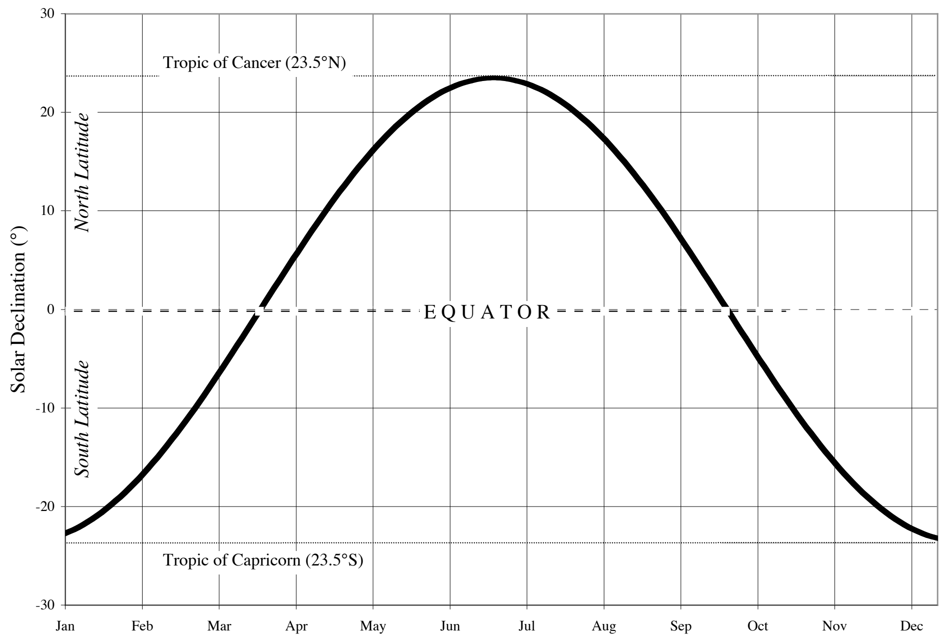
Take Home Exercises (To Be Discussed Next Week)

How did I make the graph on the previous page? I used an equation that relates the solar altitude to a number called the **solar declination**. The solar declination is the latitude at which the sun's rays shine directly down at noon. Put another way, if you were standing at the solar declination, the sun would be directly overhead at local noon. The solar declination at noon on September 21st is 0°, which is at the Equator. If the flagpole were set up at the equator, it would have no shadow at noon on September 21st!

Here's the equation I used:

$$SA = 90° - (LAT - SD)$$

LAT stands for your latitude (positive numbers indicate north latitude). SD stands for solar declination (again, positive numbers refer to latitudes north of the Equator). How do you find SD? Read it from the graph below:



…or on the table here:

Date	Solar Declination (°)
January 1	-23.1
February 1	-17.6
March 1	-8.4
April 1	3.9
May 1	14.9
June 1	22.1
July 1	23.2
August 1	18.0
September 1	7.8
October 1	-4.1
November 1	-15.3
December 1	-22.1

So, for San Diego (33°N) on September 1:

$$SA = 90° - (LAT - SD)$$

$$\Rightarrow SA = 90° - (33° - 7.8°)$$

$$\Rightarrow SA = 90° - 25°$$

$$\boxed{\therefore SA = 65°}$$

11. Either using Microsoft Excel (available for use in the Independent Learning Center) or using a piece of graph paper, try to duplicate the graph of solar altitude for San Diego from pg. 3.
12. What would a graph of solar altitude look like for the Equator (0°) and for a location in the Arctic with latitude 72°N? Make graphs of solar altitude for these two places. *What do you think a negative solar altitude might mean? What do you think a solar altitude greater than 90° might mean?*
13. Using your textbook, define the term **insolation**.
14. You can find the average monthly temperature for a variety of cities worldwide on the Web at `http://www.worldweather.org` (the World Weather Information Service, part of the World Meteorological Organization)[1]. Graph the temperature over the course of a year for San Diego and Biak, Indonesia (more or less at the Equator). Do you see a relationship between temperature and solar altitude? Describe this relationship in a few sentences, and explain why you think this relationship exists. You may want to use the term "insolation" in your explanation.

15. Using what you now know about the relationship between temperature and solar altitude and about the solar altitude at the 72°N location, make some rough predictions about the temperature throughout the year at 72°N. Find a city in the worldweather.org list that will allow you to check your predictions.

16. Here's **something strange**. Dallas, TX and San Diego have roughly the same latitude. Look up the average monthly temperatures for Dallas, and graph them on the same axes as your San Diego temperature graph. What are the differences between San Diego's and Dallas' temperatures? Why do you think the two sets of temperatures are different?

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[1] The website may list "mean daily maximum" and "mean daily minimum" temperatures instead of simply the mean temperature. For the purposes of this lab, you may *approximate* the average temperature by adding the maximum and minimum and dividing by two. E.g.:

Mean Min = 23.4°C; Mean Max = 30.0°C

Approximate Average = (23.4°+30.0°)/2 = 26.7°C

SOLAR ALTITUDE NOTES

What is the solar altitude?	
What is the temperature?	