Lab
3

Sun Angle Calculations

The purposes of this lab are to acquaint the student with the relationships between sun angle and latitude, and to explain the method of noon sun angle calculations. The relationship between solar radiation and air temperature will also be explored.

Sun Angle and Latitude

Many concepts in this lab were introduced in Lab 2

The combination of: (a) **revolution**, (b) **inclination** of the Earth's axis, and (c) the **parallelism** of its axis, causes our seasons. These variables together result in a change in the angle of the Sun above the horizon. This is the major factor that leads to changes in our air temperatures from one season to another. The higher the Sun's angle above the horizon, the more intense the heating of the Earth's surface.

Two related Sun angle variations should be noted:

1. Sun angle varies in relation to latitude. The greater the latitudinal distance of one's location from where the Sun's rays are vertical on the Earth, the lower the angle of the Sun above the horizon is for the observer.

2. Sun angle varies during the year for all latitudes because the location of the Sun's vertical rays on the Earth is constantly changing, moving between the Tropic of Capricorn and the Tropic of Cancer throughout the year.

The Sun's noontime position in the sky (which is as high as it gets) is measured by calculating the number of degrees between the horizon and the Sun's position. This angle is referred to as the solar **altitude angle**, also known as noon sun angle (or noon solar angle).

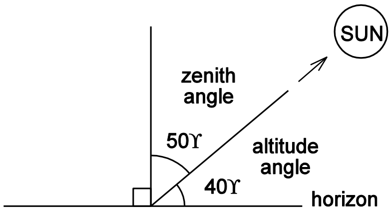

Figure 3.1

Figure 3.1 Solar Angles

The remaining angle between a point that is directly overhead and the Sun's rays is called the **zenith angle**. Therefore, the altitude angle and the zenith angle are complementary angles and always add up to 90°. In

Figure 3.1, the angle between the horizon and the Sun's rays is 40° (the altitude angle). The complement of that is 50°, which is the angle from directly overhead to the position of the Sun in the sky (the zenith angle). The zenith angle is also equal to the distance between the viewer's location and that of the vertical sun in degrees of latitude. Therefore there is a direct relationship between the altitude angle and the zenith angle where for every degree the sun is higher in the sky (altitude angle), the zenith angle decreases by one degree (one degree closer to the vertical rays of the Sun).

The above can be summarized in equation form as:

The sun angle (altitude angle) = ∠A

The zenith angle = ∠Z,

then

∠A + ∠Z = 90º, **∠A = 90º - ∠Z,** and **∠Z = 90º - ∠A.**

How to Calculate the Altitude Angle

You need to know:

1. The latitude in question (latitude of observer).
2. The latitude of the vertical Sun for the date in question (also termed the **solar declination**). This can be obtained through the use of an analemma which we provide on page 25.

You must determine:

1. The distance between the latitude in question and the latitude of the vertical Sun. This distance gives you the **zenith angle**.
2. The difference between the zenith angle and 90°. This gives you the **altitude angle** of the sun.

Example <u>Calculating the Solar Altitude Angle</u>

What is the noon sun angle at Salem, Massachusetts (43° N) on October 20?

1.	The latitude in question (of observer)	=	43° N
2.	The latitude of the vertical sun [see analemma]	=	10° S
3.	The distance between 43° N and 10° S	=	53°
4.	The zenith angle	=	53°
5.	The difference between the zenith angle and 90°	=	37° (90° – 53º)
6.	The altitude angle (at noon)	=	37°
7.	The Sun will be in	=	the Southern Horizon

Note: there are three key components:

1. latitude of the vertical sun (solar declination),
2. altitude angle, and
3. zenith angle.

If you know any two of the three you can always find the third. These calculations can be made to find the zenith angle if you are given the altitude angle, or to find the declination of the Sun (latitude of the vertical rays), or to get the latitudinal distance. The relationships are always the same.

North vs. South Horizons When Specifying Altitude Angle

An additional consideration relates to the direction in which the observer sees the Sun. When you look at the Sun at noon, you see it directly above you if you are at the latitude where the Sun is vertical. In all other situations you would view the Sun above the horizon to your North (if the vertical rays of the Sun are at a latitude north of your position), *or* you would see the Sun above the horizon to the South (if the vertical rays of the Sun are at a latitude that is south of your position). Note that this relationship is true regardless of the latitudinal label. The vertical rays of the Sun only strike between 23.5° N and 23.5° S. Therefore everywhere south of 23.5° S the Sun will always be to the north and north of 23.5° N the Sun will always be to the south. For us in Salem at 43 degrees North, the Sun is always above the southern horizon at solar noon.

Internet Resources for Sun Angle

1. This is a detailed sun angle calculator
http://www.susdesign.com/sunangle/

Here are the instructions:
http://www.susdesign.com/sunposition/instructions.html

2. This calculator is a little bit easier
http://www.geocities.com/senol_gulgonul/sun/

3. Basic calculator:
http://www.wattsun.com/resources/calculators/photovoltaic_tilt.html

Exercise #3 Lab Activity

Name: ______________________________

Sun Angles

Lab Section: ______________________________

Please show your work. If necessary please use additional paper to show work.

✎ **1) Calculate the altitude angle of the Sun at noon for the following problems:**

	Latitude of Observer	Place	Date	Latitude of Vertical Ray	Distance from 90° Sun (∠Z)	Altitude Angle (∠A)	Horizon N/S
1.	**71° N**	**Barrow**	**March 21**	**0°**	**71°**	**19°**	**S**
2.	48° N	Ulaan Baatar	March 21	0°	________	______	_____
3.	43° N	Salem	March 21	0°	________	______	_____
4.	24° N	Riyadh	March 21	0°	________	______	_____
5.	1° N	Singapore	March 21	0°	________	______	_____
6.	7° S	Dar es Salaam	March 21	0°	________	______	_____
7.	33° S	Cape Town	March 21	0°	________	______	_____
8.	79° S	Vostok	March 21	0°	________	______	_____

	Latitude of Observer	Place	Date	Latitude of Vertical Ray	Distance from 90° Sun (∠Z)	Altitude Angle (∠A)	Horizon N/S
9.	43° N	Salem	Sept. 23	_____	________	______	_____
10.	43° N	Salem	June 21	_____	________	______	_____
11.	43° N	Salem	Dec 22	_____	________	______	_____
12.	1° N	Singapore	Sept. 23	_____	________	______	_____
13.	1° N	Singapore	June 21	_____	________	______	_____
14.	1° N	Singapore	Dec 22	_____	________	______	_____

Latitude of Observer	Place	Date	Latitude of Vertical Ray	Distance from . 90° Sun (∠Z)	Altitude Angle (∠A)	Horizon N/S
15. 33° S	Cape Town	March 21	______	____________	________	______
16. 33° S	Cape Town	June 21	______	____________	________	______
17. 33° S	Cape Town	Dec 22	______	____________	________	______
18. 79° S	Vostok	March 21	______	____________	________	______
19. 79° S	Vostok	June 21	______	____________	________	______
20. 79° S	Vostok	Dec 22	______	____________	________	______

Note: each of the Places below are one of the ten places introduced at the end of Lab 1. Given the data below you should be able to determine the latitude of the place and then based on the latitude you should be able to name the place (see the list of places at the end of lab 1).

Latitude of Observer	Place	Date	Latitude of Vertical Ray	Distance from 90° Sun (∠Z)	Altitude Angle (∠A)	Horizon N/S
21. ______	______	______	0°	____________	48°	S
22. ______	______	______	23.5° S	____________	35.5°	N
23. ______	______	Nov. 22	20° S	45°	________	S
24. ______	______	______	23.5° N	____________	67.5°	N
25. ______	______	April 22	12° N	36°	________	S
26. ______	______	May 9	17° N	54°	________	S

A practical application of altitude angle

You now have an understanding of solar energy versus solar altitude angle. With this newly acquired knowledge, one can more efficiently design a new home with energy savings in mind. Depicted is a sketch of your proposed new home. On the south-facing side, you will have large picture windows that will enable you to take advantage of the delightful scenery. However, with large windows, it is important to consider energy saving ideas. **The latitude of your home is 42.5°N near Salem, MA.**

How far should you extend the eaves for better energy savings? First, determine the altitude angles (Sun angles) at solar noon for June 21 and December 22. Then, using a protractor, plot these angles to show two sets of parallel lines (one set for each season) intersecting both the top and the bottom of the south facing picture windows. One set of line represents the sun's rays for the first day of summer, while the other will show the solar rays on the first day of winter. Each set must be drawn at the proper angle showing **only** the rays that could enter through the window. Label each set of lines by season.

Now, you can extend the roof overhang with solid lines so that the **maximum winter solar radiation** will enter the window in December and so that there will be **minimal summer solar radiation** entering the window in June.

Computations

Altitude angle December 22

a. Lat. in question =
b. Lat. vert. sun =
c. Zenith angle
(dist. in degrees
between a & b) =
d. Alt. angle
(90° - the zenith angle) =

Altitude angle June 21

a. Lat. in question =
b. Lat. vert. sun =
c. Zenith angle
(dist. in degrees
between a & b) =
d. Alt. angle
(90° - the zenith angle) =

Figure 3.2 South side of a house