The Sun and Solar Energy

The sun is one of the two primary sources of energy on the Earth (stored energy from the molten core being the other). As such, understanding the sun is important to the performance of enclosures and energy consumption of buildings.

The earth revolves around the sun once every 365.2425 days in an elliptical orbit at an average distance of 154.4 million km (94.45 million miles). The earth-sun distance is 154.4 million kilometers on June 21 and 144.6 million kilometers (91.34 million miles) away in Dec 21. The earth is tilted at an angle of 23 degrees and 27 minutes with respect to its orbital plane (Figure 1). This tilt is termed the earth's declination. At noon on June 21 the sun is directly perpendicular to the earth's surface at 23.5° north. This is the reason the Tropic of Cancer is marked on a globe. On the same date, all parts of the earth south of the Antarctic circle (66.5°S, or 90° - 23.5°) will experience 24 hours of darkness, while all areas north of the Arctic circle (66.5°N) experience 24 hours of light. At noon on Dec 21 the sun is perpendicular to the Tropic of Capricorn.

At any given time and location on earth, the angle of the sun with respect to an arbitrily oriented surface can be calculated. The altitude of the sun above the horzontal, ?, the azimuth angle, ??(measured with respect to due south), the latitude L, and the declination, ? define the suns position at any time.

The earth also rotates about its axis every 24 hours.

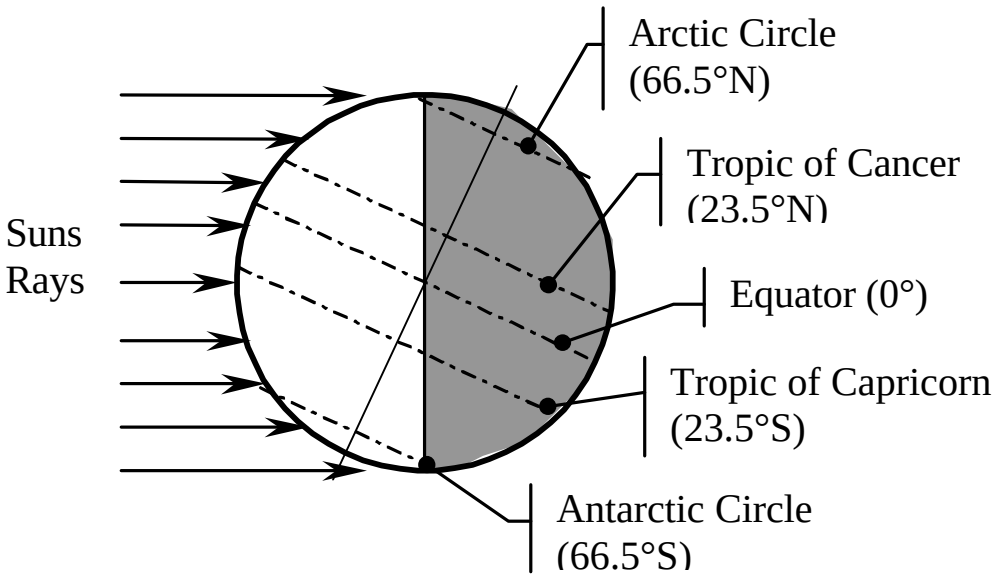


Figure 1: Earth's Tilt on December 21

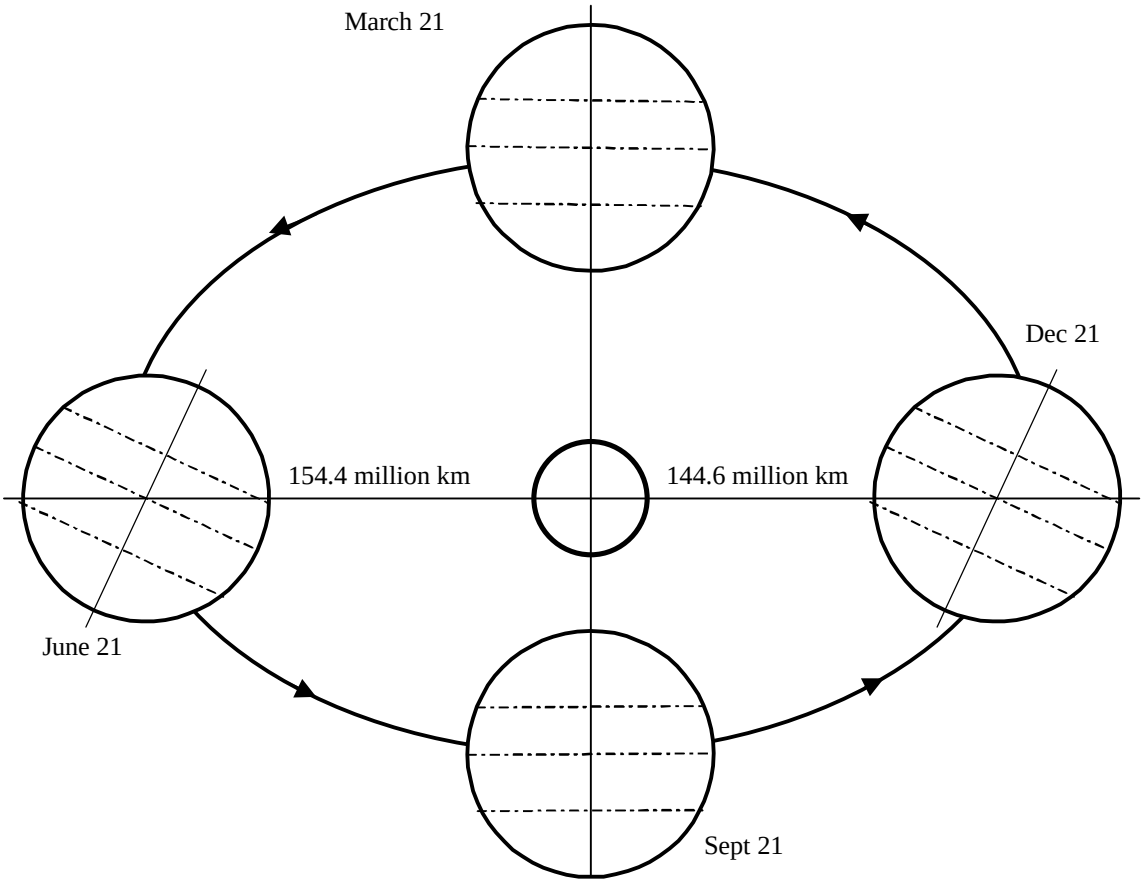


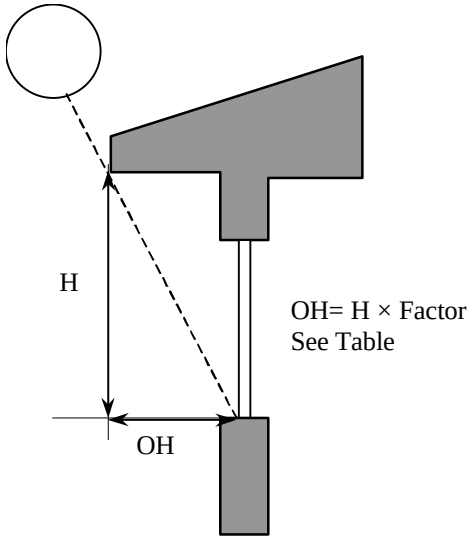
Figure 2: Earth's Orbit Around the Sun

These facts, combined with the thermal storage mass of the earth and oceans, explain the seasons, prevailing winds, the length of the day, monsoons and hurricanes, and practically all other meso-scale weather phenomenon.

On the 21st of June, the longest day of the year the angle of sun's rays with respect to the earth are also the steepest and thus the northern hemisphere receives the most intense and greatest amount of solar radiation on this date. The thermal lag of the earth delays the hottest days of the year for another month however. Similarly, the least solar energy is delivered in Dec 21, and the coldest days of the winter tend to be a month later.

It is therefore easy to see how overhangs on a building can help control solar radiation. For example, at 40 °N, the angle of the sun above the horizon at solar noon on June 21st will be 90-40+23.5=73.5° whereas on Dec 21st it will be only 90-40-23.5=26.5°. This knowledge of the sun is critical for the proper design of buildings (heating, cooling, daylighting) as well as for building enclosures (since the sun affects enclosure temperatures and the deterioration of some materials).

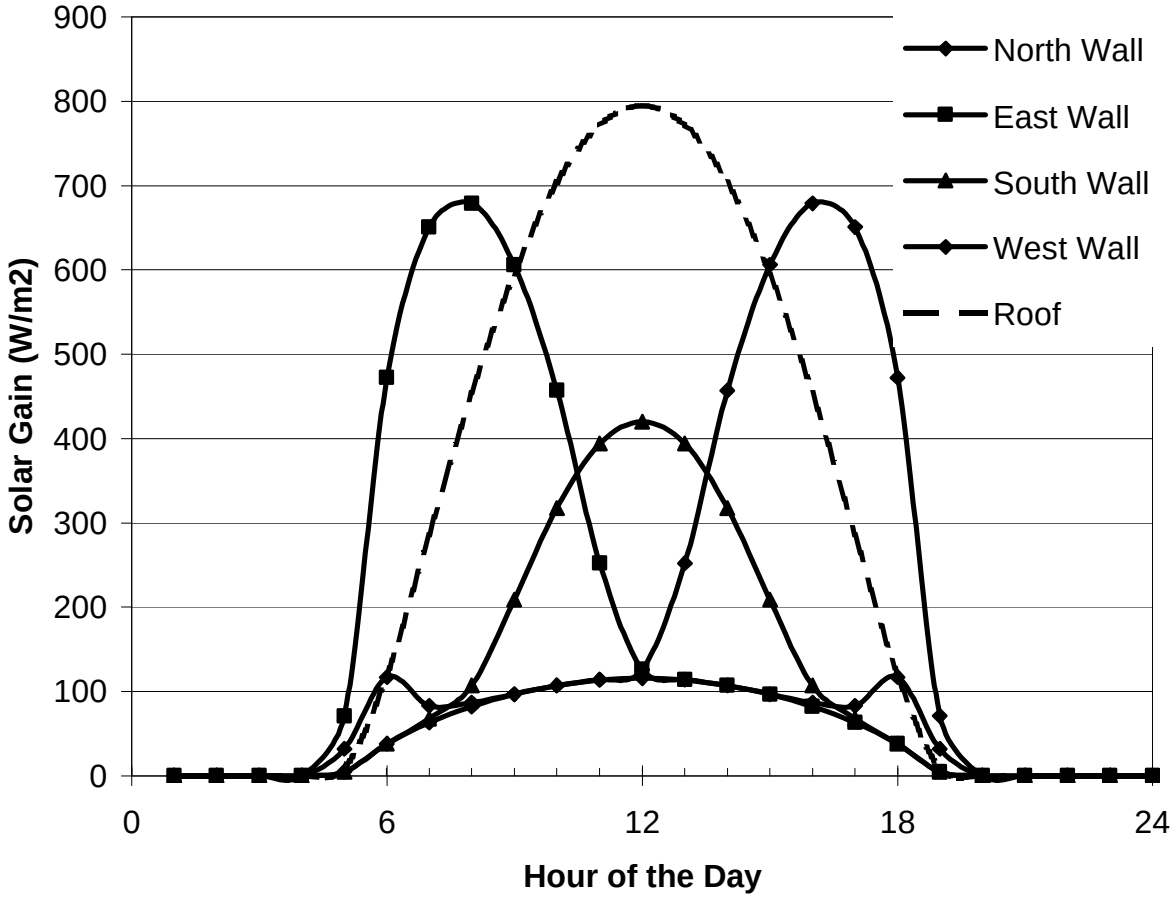
The impact of the sun on any arbitrary plane surface at any time of the year can be accurately calculated. Only the occurrence of clouds, fog, ground reflectance, and neighbouring buildings add a degree of randomness to the solar radiation striking a building enclosure.



Degrees Latitude	June 21 Only	May 10 to Aug 1
28	0.09	0.18
32	0.16	0.25
36	0.22	0.33
40	0.29	0.40
44	0.37	0.50
48	0.45	0.59

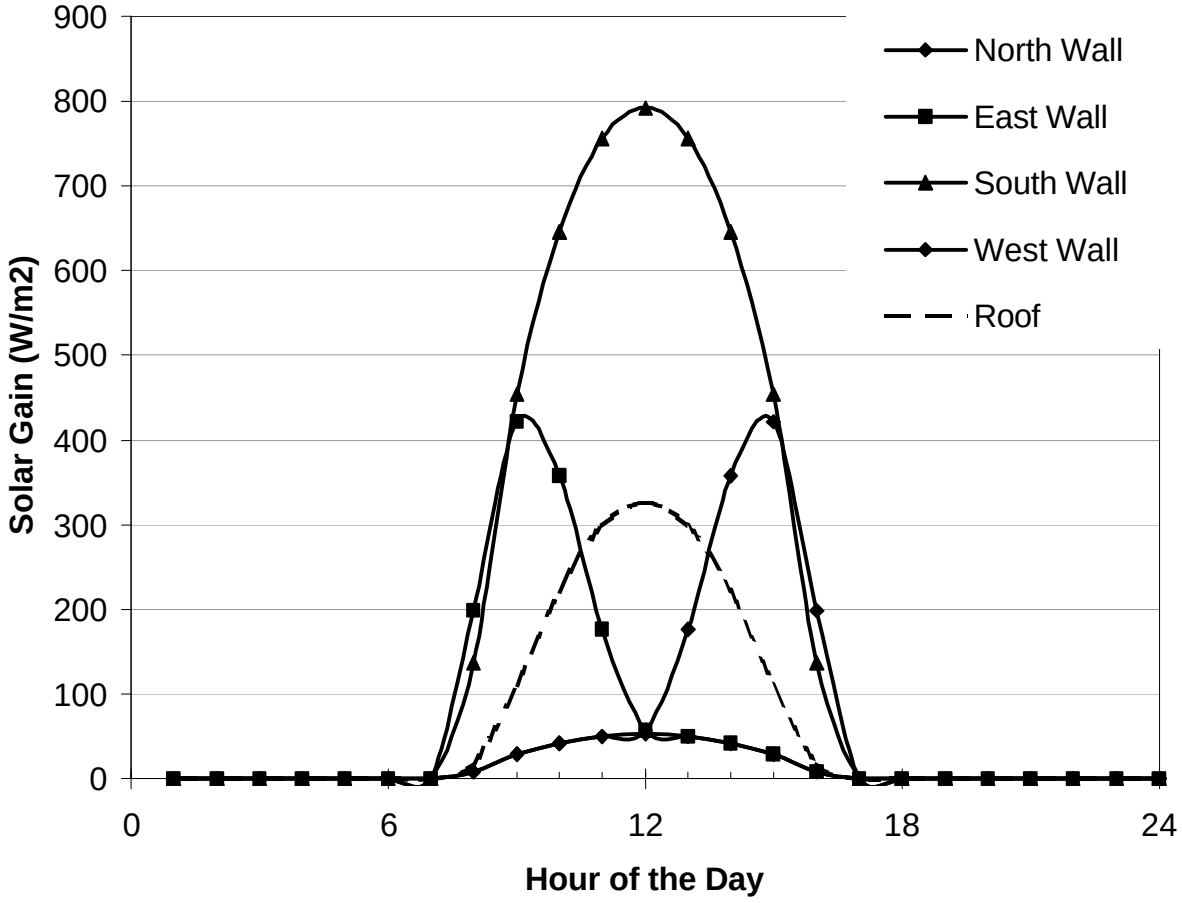
Figure 3: Shading Factors for South-Facing Overhangs (100% Shade)

Hour	North Wall	East Wall	South Wall	West Wall	Roof
1	0	0	0	0	0
2	0	0	0	0	0
3	0	0	0	0	0
4	0	0	0	0	0
5	32	71	5	5	9
6	**117**	472	38	38	119
7	83	651	68	63	286
8	87	**679**	107	82	454
9	97	606	209	97	595
10	107	457	318	107	704
11	114	252	394	114	772
12	116	126	**420**	126	**795**
13	114	114	394	252	772
14	107	107	318	457	704
15	97	97	209	606	595
16	87	82	107	**679**	454
17	83	63	68	651	286
18	**117**	38	38	472	119
19	32	5	5	71	9
20	0	0	0	0	0
21	0	0	0	0	0
22	0	0	0	0	0
23	0	0	0	0	0
24	0	0	0	0	0
TOTAL	1390	3820	2698	3820	6673



Solar Gains - Clear Day on July 21 @ 45ºN (W/m^2)

Hour	North Wall	East Wall	South Wall	West Wall	Roof
1	0	0	0	0	0
2	0	0	0	0	0
3	0	0	0	0	0
4	0	0	0	0	0
5	0	0	0	0	0
6	0	0	0	0	0
7	0	0	0	0	0
8	8	199	137	8	17
9	29	**422**	454	29	111
10	42	358	646	42	222
11	50	177	756	50	299
12	**53**	57	**792**	57	**326**
13	50	50	756	177	299
14	42	42	646	358	222
15	29	29	454	**422**	111
16	8	8	137	199	17
17	0	0	0	0	0
18	0	0	0	0	0
19	0	0	0	0	0
20	0	0	0	0	0
21	0	0	0	0	0
22	0	0	0	0	0
23	0	0	0	0	0
24	0	0	0	0	0
TOTAL	311	1342	4778	1342	1624



Solar Gains - Clear Day on January 21 @ 45ºN (W/m^2)