

APPENDIX I

Solar time and local time

The time lines refer to solar time in all the sun path diagrams such as is shown Figure I.1. For northern latitudes above the Tropics, Solar noon occurs when the sun is due South and lies in the meridian plane for the particular location as shown in Figure I.2. For southern latitudes outside the tropics the sun will always be due North at solar noon.

However, nowadays we generally set our watches to clock time and this is different from solar time.

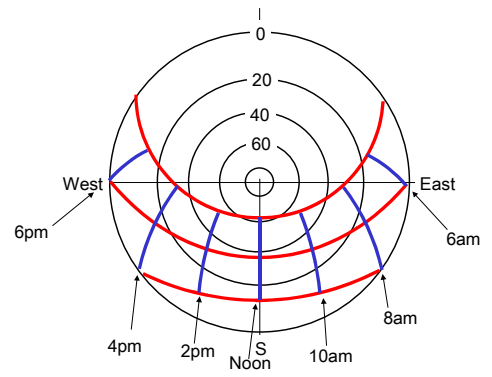


Figure I.1 – Sunpath diagram

Effect of Longitude

Solar noon is that time when the sun passes through the meridian plane, and it is clear that the instant at which this happens will be different at different longitudes because of the Earth's rotation. The Longitude is by convention positive west of Greenwich.

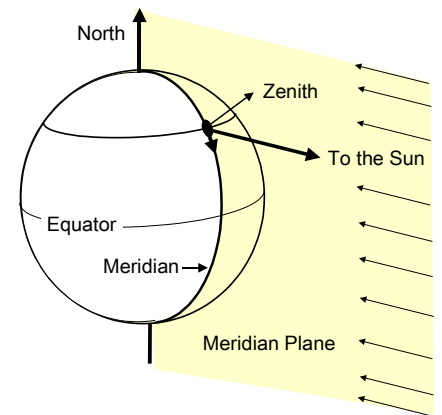
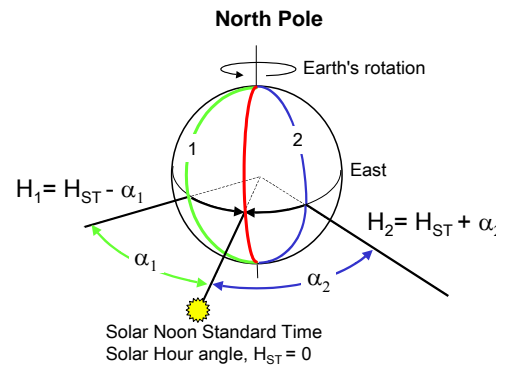


Figure I.2 – Sun at Noon

The Earth rotates 360° to the East about every 24 hours and therefore for each difference of 1 degree in longitude between two locations, there will a time interval between solar noon of,

$$\frac{24}{360} \times 60 \text{ min} = 4 \text{ minutes.}$$

If the noon of Clock Time is based upon the time of solar noon at a standard longitude, then the Solar Time at another location will be related to the Clock Time at the standard longitude as follows,



$$T_{\text{LOCAL_SOLAR}} = T_{\text{CLOCK}} + \frac{(\text{Longitude}^{\circ}_{\text{CLOCK}} - \text{Longitude}^{\circ}_{\text{LOCAL}})}{15}$$

This can be seen diagrammatically in Figure I.3 where the hour angles are shown for locations east and west of the standard meridian.

Figure I.3 – Hour angles at longitudes

Effect of elliptical orbit

The Earth's orbit about the sun is elliptical as shown in Figure I.4. One of Kepler's laws of planetary motion states that the area of sector swept in unit time is constant. Because over sector 1 the distance between the Earth and the sun is smaller than over sector 2, the angle swept through over sector 1, ϕ_1 is greater than that over sector 2, ϕ_2 . Thus the angle orbited by the Earth about the Sun changes over the year.

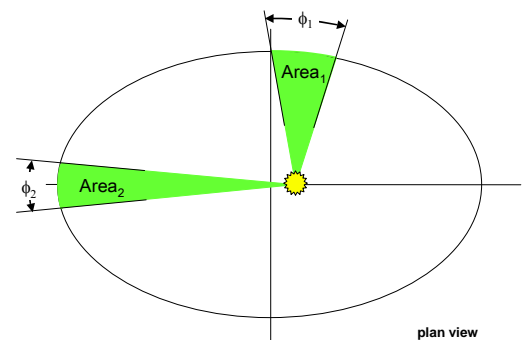


Figure I.4 – Angle of orbit

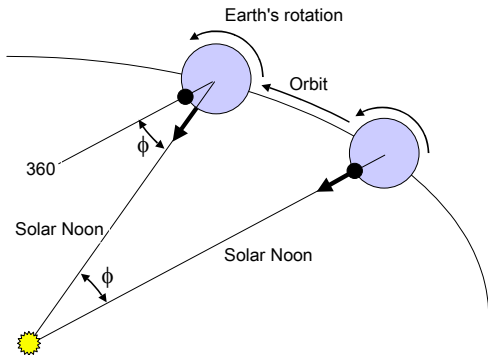


Figure I.5 – Angle rotated between noon

Solar noon occurs when the meridian is in line with the sun, and as Figure I.5 shows, the angle that the Earth rotates between the noon of one day and the next is,

$$360^\circ + \phi.$$

Thus, because ϕ changes through the year and the rate of rotation stays constant, the length of day will change through the year.

Effect of the Earth's tilt

The hour angle used to describe the degree to which the Earth rotates about its axis is measured in the equatorial plane. However, the angle that describes the angle the between sunrise and solar noon is measured in the ecliptic plane as shown in Figure I.6 The relation between the two angles changes through the year and this leads to another factor changing the length of a solar day.

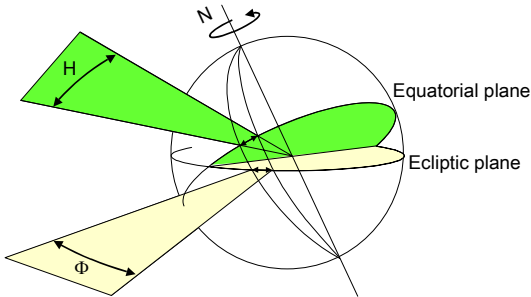


Figure I.6 – Effect of Tilt on Day-length

Equation of Time

It is rather inconvenient to incorporate a change in the length of day into clock time. Therefore it is assumed for Clock Time that the length of day is constant and the average day length throughout the year. Thus the standard clock time used in this country is based upon noon being taken to be at Greenwich and is known as Greenwich Mean Time.

The correction to account for the difference between the changing length of day and the mean day length is known as the Equation of Time. Figure I.7 shows the individual corrections for orbit and tilt and the combined correction known as the Equation of Time.

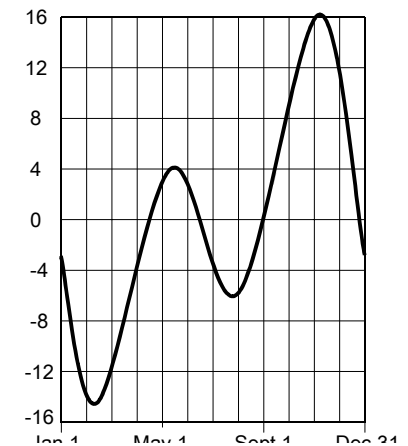
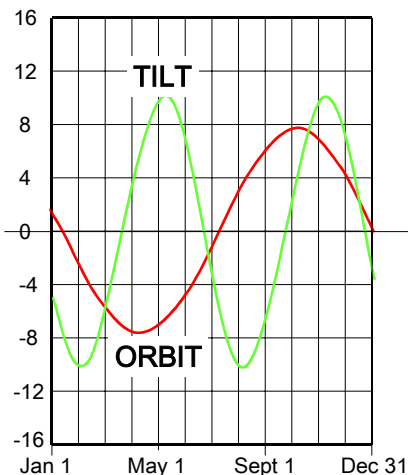


Figure 1.7 – Equation of TIME

When the Equation of Time is positive the solar noon occurs before clock noon, and so if clock time is known for the meridian then the solar time will be given by:

$$T_{SOLAR} = T_{CLOCK} + ET$$

An algorithm for the Equation of Time is :

Equation of time = ET

$$ET = 0.170 \sin \left[4\pi \left(\frac{N-80}{373} \right) \right] - 0.129 \sin \left[2\pi \left(\frac{N-8}{355} \right) \right] \text{ hours}$$

N = day number where Jan 1 is 1, and 28 days in February

Daylight Saving

An additional correction is sometimes applied to a standard time in order to effect Daylight saving. Sunrise and Sunset are symmetrical about solar noon, and in Winter in the UK this fits in quite well with the way people generally live. People are generally active from dawn to dusk and thus fully exploit the available daylight.

$$T_s = T_c + \left(\frac{\text{Longitude}_{\text{Standardtime}} - \text{Longitude}_{\text{locale}}}{15^\circ} \right) + ET \pm T_{DS}$$

T_s = Solar time,

T_c = Clock time,

ET = Equation of time correction

T_{DS} = Daylight Saving correction

However, in summer time, when dawn occurs at 4am in the morning, there are perhaps 3 hours of daylight that are not fully utilised because we have not arisen from our beds. If the clocks are put forward by one hour, then this will cause dawn to occur later in clock time, and also dusk to occur later. This will mean that because people do not go to bed until late in the evening, they will be able to profitably use the extra hour of daylight between 8pm and 9pm when they are still active.

$$T_{\text{SOLAR_TIME}} = T_{\text{GMT}} - DS$$

Note that Daylight Saving is positive when clock time is later than standard time.

Combining these effects

Thus if you wish to know where the sun is at a particular time of day, then by applying the following correction you will be able to establish the solar time that you require and this can be used to establish the position on the sunpath diagram that you require.

$$T_{\text{LOCAL_SOLAR}} = T_{\text{CLOCK}} + \frac{(\text{Longitude}^\circ_{\text{CLOCK}} - \text{Longitude}^\circ_{\text{LOCAL}})}{15} + ET - DS$$

If it is noted that hour lines on the Sunpath diagram are sketched in without a great deal of accuracy, then it is not really sensible to apply all these corrections in all circumstances. The maximum effect of the Equation of Time is about a quarter of an hour and the as Longitude of Bath is 2.25° West the longitudinal correction equivalent to only 10min. Thus it is probably not worth taking either of these into account in general design in Bath. However, it might be worth considering the effects of daylight saving because British Summer Time is one hour ahead Greenwich Mean Time.