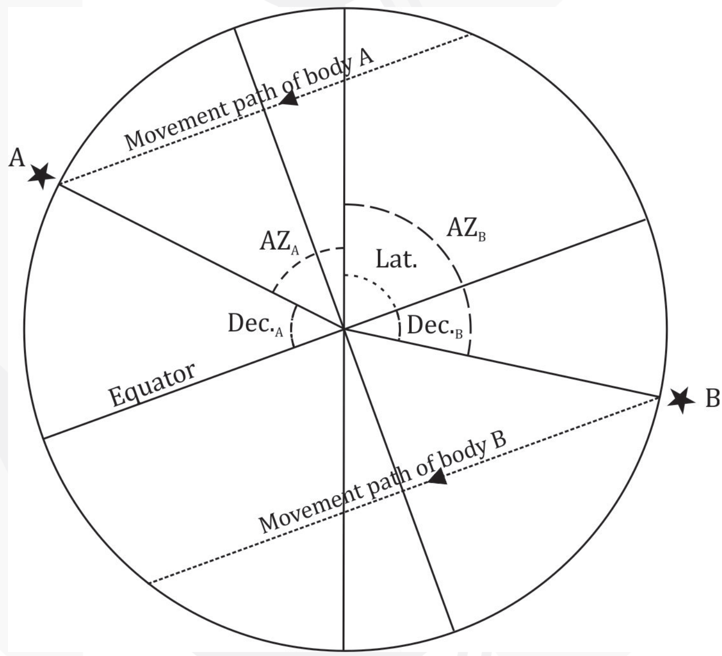
# Rising, Setting and Twilight

The rotation of the earth on its own axis causes the phenomenon of the rising and setting of all celestial bodies. Generally, the celestial bodies seem to appear at the eastern horizon, cross the sky and then disappear to the western horizon. However, some bodies are always visible above the horizon or always visible below the horizon, depending on the latitude of the observer and the declination of the celestial body. The body that is always visible above the horizon is called *circumpolar*; in this case, the body is in the lower meridian and the zenith distance of the body is less than 90° (body A). A heavenly body is always invisible if it never rises above the horizon when its zenith distance is greater than 90° at the instant of upper meridian passage (body B).




**Time of Rising and Setting**

In navigation, rising or setting is when the upper limb of the body is on the visible horizon. The time of sunrise and sunset is given on the right-hand side of the right-hand page in the daily pages of the Nautical Almanac. The figure is the Local Mean Time (LMT) for the middle day of the three days on each page. In the low and moderate latitudes, the daily change of the time of sunrise or sunset is very little over three days, so the time of middle day can be used for other dates on the same page without interpolation. In the high latitudes, interpolation may be necessary for more accuracy. In order to obtain UT, apply the longitude in time to LMT as follows:

$$UT = LMT \begin{array}{l} + \text{West Longitude} \\ - \text{East Longitude} \end{array}$$

***Procedure for finding times of sunrise and sunset***

1. From the daily page of the Nautical Almanac, extract the LMT for the latitude, which is the next numeral smaller than the observer's latitude;

2. Extract the LMT for the latitude, which is the next numeral higher than the observer's latitude;

3. Calculate the difference between the above LMTs, and use Table I in the back of the Nautical Almanac to obtain the correction for observer's latitude;

4. Apply the above latitude correction (3) to the LMT in (1) to obtain the LMT for the observer's latitude;

5. Apply the longitude in time to the LMT (4) to obtain UT.

Example 1

Find UT of sunrise and sunset on 18th of July 2008 for latitude 47°28´N and longitude 098°46´W:

| | Sunrise | Sunset |
|---|---|---|
| LMT (45°N) | $18^d\ 04^h31^m$ | $18^d\ 19^h41^m$ |
| LMT (50°N) | $18^d\ 04^h11^m$ | $18^d\ 20^h01^m$ |
| difference | $20^m$ | $20^m$ |
| Latitude 47°28′N correction (table I) | $-10^m$ | $+10^m$ |
| **LMT** (47°28′N, 098°46′W) | $18^d\ 04^h21^m$ | $18^d\ 19^h51^m$ |
| Longgitude in time (098°46′W) | $+6^h35^m$ | $+6^h35^m$ |
| **UT** (47°28′N, 098°46′W) | $18^d\ 10^h56^m$ | $19^d\ 02^h26^m$ |

Example 2

Find UT of sunrise and sunset on 24th of October 2008 for latitude 50°43´S and longitude 121°28´E:

| | Sunrise | Sunset |
|---|---|---|
| LMT (50°S) | $24^d\ 04^h39^m$ | $24^d\ 18^h50^m$ |
| LMT (52°S) | $24^d\ 04^h34^m$ | $24^d\ 18^h55^m$ |
| difference | $5^m$ | $5^m$ |
| Latitude 50°43′S correction (table I) | $-2^m$ | $+2^m$ |
| **LMT** (50°43′S, 121°28′E) | $24^d\ 04^h37^m$ | $24^d\ 18^h52^m$ |
| Longgitude in time (121°28′E) | $-8^h06^m$ | $-8^h06^m$ |
| **UT** (50°43′S, 121°28′E) | $23^d\ 20^h31^m$ | $24^d\ 10^h46^m$ |

In the example above, the time of sunrise and sunset of 24th of October uses the same table as 25th and 26th of October, where 25th is the middle day. Basically, the information obtained from the table is that of 25th of October. There is only a slight change in LMT between each day, so interpolation is unnecessary. Generally, in the low latitudes, the times of setting and rising of the sun change very slightly over three days, so interpolation can be omitted.

Finding the time of moonrise and moonset is similar to finding the time of sunrise and sunset, but more complicated due to the rapid change of GHA and the declination of the moon at an irregular rate. Therefore, the mean times of rising and setting at the Greenwich Meridian cannot be considered as the LMT for any other meridians, as in the case of the sun; hence, the extra correction in longitude is needed. Thus, the time of moonrise and moonset are given in the Nautical Almanac in daily basic; then, if in east longitude, interpolation is needed with the preceding day, and if in west longitude, interpolation is needed with the following day. For convenience, the times of moonrise and moonset of the day following the last day in the period are also given.

***Procedure for finding times of Moonrise and Moonset***

1. From the daily page of Nautical Almanac, extract the LMT for the latitude next smaller than the observer's latitude;

2. Extract the LMT for the latitude next higher than the observer's latitude;

3. Calculate the difference between above LMTs and use table I at the back of the Nautical Almanac, to obtain the correction for observer's latitude;

4. Repeat steps 1, 2 and 3 for the day following the given date, if in west longitude; or for the day preceding, if in east longitude.

5. Calculate the difference between these two days and use table II also at the back of the Nautical Almanac, to obtain the correction for observer's longitude, or by the following formula:

$$\text{Longitude Correction} = \text{Daily difference} \times \frac{\text{longitude}}{360}$$

6. Apply longitude in time to LMT to obtain UT.

Example 3 Find UT of moonrise on 18th of July 2008 for latitude 42°42′ N and longitude 110°46′ E:

| | Proceeding Day | Moonrise |
|---|---|---|
| LMT (40°N) | $17^d\ 19^h13^m$ | $18^d\ 19^h47^m$ |
| LMT (45°N) | $17^d\ 19^h32^m$ | $18^d\ 20^h03^m$ |
| difference | $19^m$ | $16^m$ |
| Latitude 42°42′N correction (table I) | $+11^m$ | $+8^m$ |
| | $17^d\ 19^h24^m$ | $18^d\ 19^h55^m$ |
| difference ($17^{th}$ and $18^{th}$) | | $31^m$ |
| Longitude 110°46′E correction (table II) | | $-10^m$ |
| **LMT** (42°42′N, 110°46′E) | | $18^d\ 19^h45^m$ |
| Longgitude in time (110°46′E) | | $-7^h23^m$ |
| **UT** (42°42′N, 110°46′E) | | $18^d\ 12^h22^m$ |

Example 4 Find UT of moonset on 26th of October 2008 for latitude 20°56′ S and longitude 080°42′ W:

| | Moonset | Following Day |
|---|---|---|
| LMT (20°S) | $26^d\ 16^h07^m$ | $27^d\ 16^h59^m$ |
| LMT (30°S) | $26^d\ 16^h13^m$ | $27^d\ 17^h10^m$ |
| difference between 20°S and 30°S | $6^m$ | $11^m$ |
| Latitude 20°56′S correction (table I) | $+0^m$ | $+1^m$ |
| | $26^d\ 16^h07^m$ | $27^d\ 17^h00^m$ |
| difference ($26^{th}$ and $27^{th}$) | $53^m$ | |
| Longitude 80°42′W correction (table II) | $+12^m$ | |
| **LMT** (20°56′S, 080°42′W) | $26^d\ 16^h19^m$ | |
| Longgitude in time (080°42′W) | $+5^h23^m$ | |
| **UT** (20°56′S, 080°42′W) | $26^d\ 21^h42^m$ | |

**Twilight** Twilight is the period of incomplete darkness before sunrise and after the sunset. So the morning twilight ends at sunrise, when the upper limb of the sun just appears above the visible horizon, and evening twilight starts at sunset, when the upper limb of the sun just disappears below the visible horizon. The period of twilight is very important to the navigator, because in this period the visible horizon can still be seen and the celestial bodies on the sky are bright enough to be observed by the sextant. There are three stages of twilight:

1. **Civil twilight** is the interval of time between visible sunrise or sunset and the time when the centre of the sun is 6° below the rational horizon.

2. **Nautical twilight** is the interval of time between visible sunrise or sunset and the time when the centre of the sun is 12° below the rational horizon.

3. **Astronomical twilight** is the interval of time between visible sunrise or sunset and the time when the centre of the sun is 18° below rational horizon.

The twilight period is longer in higher latitudes than in lower latitudes. The period of astronomical twilight is the limit of the full darkness; it is too dark for observation, so only civil twilight and nautical twilight periods are considered for navigational purposes.

The procedure to find the twilight is same as finding the sunrise and sunset.

Example 5 Find UT of the morning twilight on 17th April 2008 for position 38°45´N, 40°50´W:

| | Nautical | Civil |
|---|---|---|
| LMT (35°N) | $17^d\ 04^h29^m$ | $17^d\ 05^h00^m$ |
| LMT (40°N) | $17^d\ 04^h19^m$ | $17^d\ 04^h52^m$ |
| difference | $10^m$ | $8^m$ |
| Latitude 38°45′N correction (table I) | $-7^m$ | $-6^m$ |
| **LMT** (38°45′N, 040°50′W) | $17^d\ 04^h22^m$ | $17^d\ 04^h54^m$ |
| Longgitude in time (040°50′W) | $+2^h43^m$ | $+2^h43^m$ |
| **UT** (38°45′N, 040°50′W) | $17^d\ 07^h05^m$ | $17^d\ 07^h37^m$ |

In the example above, similarly to finding the time of sunrise and sunset, the time of twilight of 17th April uses the same table as 15th and 16th April, where 16th April is the middle day. Basically, the information obtained from the table is that of 16th April. There is only a slight change in LMT, so interpolation is unnecessary. Generally, in the low latitudes, the times of setting and rising change very slightly over three days, so interpolation can be omitted.