U.S. Naval Observatory Astronomical Applications Department

Rise, Set, and Twilight Definitions

(For specific rise, set, and twilight computations, see Complete Sun and Moon Data for One Day or One Year's table of Sunrise/Sunset, Moonrise/Moonset, or Twilight Times in **Data Services**.)

Horizon: Wherever one is located on or near the Earth's surface, the Earth is perceived as essentially flat and, therefore, as a plane. The sky resembles one-half of a sphere or dome centered at the observer. If there are no visual obstructions, the apparent intersection of the sky with the Earth's (plane) surface is the horizon, which appears as a circle centered at the observer. For rise/set computations, the observer's eye is considered to be on the surface of the Earth, so that the horizon is geometrically exactly 90 degrees from the local vertical direction.

Rise, Set: During the course of a day the Earth rotates once on its axis causing the phenomena of rising and setting. All celestial bodies, stars and planets included, seem to appear in the sky at the horizon to the East of any particular place, then to cross the sky and again disappear at the horizon to the West. The most noticeable of these events, and the most significant in regard to ordinary affairs, are the rising and setting of the Sun and Moon. Because the Sun and Moon appear as circular disks and not as points of light, a definition of rise or set must be very specific, for not all of either body is seen to rise or set at once.

> **Sunrise and sunset** conventionally refer to the times when the upper edge of the disk of the Sun is on the horizon, considered unobstructed relative to the location of interest. Atmospheric conditions are assumed to be average, and the location is in a level region on the Earth's surface.
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> **Moonrise and moonset** times are computed for exactly the same circumstances as for sunrise and sunset. However, moonrise and moonset may occur at any time during a 24 hour period and, consequently, it is often possible for the Moon to be seen during daylight, and to have moonless nights. It is also possible that a moonrise or moonset does not occur relative to a specific place on a given date.

Transit: The transit time of a celestial body refers to the instant that its center crosses an imaginary line in the sky - the observer's meridian - running from north to south. For observers in low to middle latitudes, transit is *approximately* midway between rise and set, and represents the time at which the body is highest in the sky on any given day. At high latitudes, neither of these statements may be true - for example, there may be several transits between rise and set. The transit of the Sun is local solar (sundial) noon. The difference between the transit times of the Sun and Moon is closely related to the Moon's phase. The New Moon transits at about the same time as the Sun; the First Quarter Moon transits about 6 hours after the Sun; the Full Moon transits about 12 hours after/before the Sun; and the Last Quarter Moon transits about 6 hours before the Sun.

Twilight: Before sunrise and again after sunset there are intervals of time, twilight, during which there is natural light provided by the upper atmosphere, which does receive direct sunlight and reflects part of it toward the Earth's surface. Some outdoor activities may be conducted without artificial illumination during these intervals, and it is useful to have some means to set limits beyond which a certain activity should be assisted by artificial

lighting. The major determinants of the amount of natural light during twilight are the state of the atmosphere generally and local weather conditions in particular. Atmospheric conditions are best determined at the actual time and place of events. Nevertheless, it is possible to establish useful, though necessarily approximate, limits applicable to large classes of activities by considering only the position of the Sun below the local horizon. Reasonable and convenient definitions have evolved.

Civil twilight is defined to begin in the morning, and to end in the evening when the center of the Sun is geometrically 6 degrees below the horizon. This is the limit at which twilight illumination is sufficient, under good weather conditions, for terrestrial objects to be clearly distinguished; at the beginning of morning civil twilight, or end of evening civil twilight, the horizon is clearly defined and the brightest stars are visible under good atmospheric conditions in the absence of moonlight or other illumination. In the morning before the beginning of civil twilight and in the evening after the end of civil twilight, artificial illumination is normally required to carry on ordinary outdoor activities. Complete darkness, however, ends sometime prior to the beginning of morning civil twilight and begins sometime after the end of evening civil twilight.

Nautical twilight is defined to begin in the morning, and to end in the evening, when the center of the sun is geometrically 12 degrees below the horizon. At the beginning or end of nautical twilight, under good atmospheric conditions and in the absence of other illumination, general outlines of ground objects may be distinguishable, but detailed outdoor operations are not possible, and the horizon is indistinct.

Astronomical twilight is defined to begin in the morning, and to end in the evening when the center of the Sun is geometrically 18 degrees below the horizon. Before the beginning of astronomical twilight in the morning and after the end of astronomical twilight in the evening the Sun does not contribute to sky illumination; for a considerable interval after the beginning of morning twilight and before the end of evening twilight, sky illumination is so faint that it is practically imperceptible.

Technical Definitions and Computational Details

Sunrise and sunset. For computational purposes, sunrise or sunset is defined to occur when the geometric zenith distance of center of the Sun is 90.8333 degrees. That is, the center of the Sun is geometrically 50 arcminutes below a horizontal plane. For an observer at sea level with a level, unobstructed horizon, under average atmospheric conditions, the upper limb of the Sun will then appear to be tangent to the horizon. The 50-arcminute geometric depression of the Sun's center used for the computations is obtained by adding the average apparent radius of the Sun (16 arcminutes) to the average amount of atmospheric refraction at the horizon (34 arcminutes).

Moonrise and moonset. Moonrise and moonset are defined similarly, but the situation is computationally more complex because of the nearness of the Moon and the eccentricity of its orbit. If the computations are carried out using coordinates of the Moon with respect to the Earth's center (the usual method), then moonrise or moonset is defined to occur when the geometric zenith distance of the center of the Moon is

90.5666 degrees + Moon's apparent angular radius - Moon's horizontal parallax

Under normal atmospheric conditions at sea level, the upper limb of the Moon will then appear to be tangent with a level, unobstructed horizon. No account is taken of the Moon's phase; that is, the Moon is always regarded as a disk in the sky and the upper limb might be dark. Here again, a constant of 34 arcminutes (0.5666 degree) is used to account for atmospheric refraction. The Moon's apparent radius varies from 15 to 17 arcminutes and its horizontal parallax varies from 54 to 61 arcminutes. Adding all the terms above together, the center of the Moon at rise or set is geometrically 5 to 10 arcminutes above the observer's "geocentric horizon" - the horizontal plane that passes through the Earth's center, orthogonal to the observer's local vertical.

Accuracy of rise/set computations. The times of rise and set phenomena cannot be precisely computed, because,

in practice, the actual times depend on unpredictable atmospheric conditions that affect the amount of refraction at the horizon. Thus, even under ideal conditions (e.g., a clear sky at sea) the times computed for rise or set may be in error by a minute or more. Local topography (e.g., mountains on the horizon) and the height of the observer can affect the times of rise or set even more. It is not practical to attempt to include such effects in routine rise/set computations.

The accuracy of rise and set computations decreases at high latitudes. There, small variations in atmospheric refraction can change the time of rise or set by many minutes, since the Sun and Moon intersect the horizon at a very shallow angle. For the same reason, at high latitudes, the effects of observer height and local topography are magnified and can substantially change the times of the phenomena actually observed, or even whether the phenomena are observed to occur at all.

Twilight. There are three kinds of twilight defined: civil twilight, nautical twilight, and astronomical twilight. For computational purposes, civil twilight begins before sunrise and ends after sunset when the geometric zenith distance of the center of the Sun is 96 degrees - 6 degrees below a horizontal plane. The corresponding solar zenith distances for nautical and astronomical twilight are 102 and 108 degrees, respectively. That is, at the dark limit of nautical twilight, the center of the Sun is geometrically 12 degrees below a horizontal plane; and at the dark limit of astronomical twilight, the center of the Sun is geometrically 18 degrees below a horizontal plane.

This information is derived from the Explanatory Supplement to the Astronomical Almanac, ed. P. K. Seidelmann (1992), pp 482ff.

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