Inequality At The Equinoxes

BY PROFESSOR BEN BUCKNER

THE EQUINOXES, which occur on approximately September 23 and March 20, are the times when the sun rises directly east and sets directly west. Most of us were taught that the length of daytime and nighttime are equal on the equinox dates and many probably believe that the sun rises precisely at 6:00 a.m. and sets at 6:00 p.m. at the equinoxes. The times for sunrise and sunset are not 6 o'clock. For example, in East Tennessee, we are told that the sun rises at 7:18 a.m. and sets at 7:26 p.m. on September 23 and that is rises at 6:33 a.m. and sets at 6:41 p.m. on March 20. Obviously, all of these times differ considerably from 6:00 a.m. and 6:00 p.m. and there are not 12 hours between sunrise and sunset. Why these discrepancies?

There are at least five reasons why the times of sunrise and sunset are not exactly 12 hours apart and at 6 o'clock on the equinox dates. First of all, the September date (Autumnal Equinox) contains a one-hour shift for daylight saving time. Subtracting an hour from the radio announcer's predicted clock time gives 6:18 a.m. and 6:26 p.m. on a standard time system, a lot closer to 6 o'clock, but still several minutes from it.

The second reason is that the times of sunrise and sunset vary with the east or west longitudinal distance from the centre of the time zone. The sun rises or sets 4 minutes later for each degree of longitude as we move west, or 4 minutes earlier for each degree of longitude east of a particular location. Time zones are centred on longitude values of 75°, 90°, 105° and 120° for the Eastern, Central, Mountain and Pacific Zones in the U.S. Johnson City, Tennessee is at longitude 82°20′, located in the Eastern time zone. Therefore, it is 7°20′ west of the Central meridian line of 75°, and this equates to 29.3 minutes of time **later** than sunrise or sunset would be in the centre of the zone several states to the east of us. But, it is seen that this adjustment to the published times will not result in 6 o'clock times, or in equal days and nights since the time zone shift is the same both morning and afternoon.

Two additional factors relate to the angular diameter of the sun and atmospheric refraction. Broadcast times of sunrise and sunset are for the instant the observer would first see the leading edge of the sun at sunrise and last see the trailing edge of the sun at sunset, not for the time when the centre of the sun is on the horizon. Furthermore, the light is refracted (bent) by the atmosphere of the earth and we see it rising before it actually has done so, and we see it after it has actually set. The refraction effect is about 3 minutes and the time for the sun to move over one-half its diameter is another minute. The combined effect is approximately 4 minutes in the latitudes of the 48 states.

At this point, we could pause to do a little arithmetic. If we start with our assumption of 6:00 a.m. and 6:00 p.m. for sunrise and sunset, add an hour for daylight savings time, add 29.3 minutes for the location in the time zone, subtract 4 minutes at sunrise and add 4 minutes at sunset, the result is an expected sunrise at approximately 7:25.3 and sunset at 7:33.3. But this is still different from what the almanac or the weatherman says by over 7 minutes.

The last variable to consider is what is called "equation of time". Solar time is not uniform because the earth moves at a varying speed along its elliptical orbit around the sun. But, watches and clocks are made to run at a uniform rate. It wouldn't be practical to cause all of the world's timepieces to speed up or slowdown to match the varying solar time, so differences are regulated in the world of astronomy and surveying by the "equation of time". This is a time difference between uniform (civil) clock time and true solar time. It reaches a maximum of about 16 minutes at one point during the year, but most of us never notice. It is approximately negative 7.3 minutes on the date of the Autumnal Equinox. When this negative correction is added to the times in the previous paragraph, it is seen that the broadcast times of 7:18 a.m. for sunrise and 7:26 p.m. for sunset are correct for our clock set to Eastern Daylight Savings Time in Johnson City, Tennessee. Similar calculations, with consideration for the fact that equation of time is positive 7.3 minutes at the Vernal Equinox, will yield sunrise at 6:33 a.m. and 6:41 p.m. on March 20 at this location.

Except at the equinox, sunrise and sunset times also vary with latitude (north-south location). During most of the year the sun rises later and sets earlier in Canada than in the 48 states, for example. Likewise, it rises earlier and sets later in Mexico than in most of the continental U.S. along any particular longitudinal line. North and South location also cause some other effects in some of the variables discussed, but these are small when considering time to only the nearest minutes in the 48 states. Local topography also affects actual time of sunrise or sunset as viewed by the observer.

In order to complete the discussion and to clear any possible confusion as to times of sunrise and sunset at the winter solstice (December 22) and summer solstice (June 22), these times are similarly affected by the above variables and we might especially notice that even after December 22, the sun continues to rise later and later for nearly two weeks before we are again blessed with more morning daylight. Likewise, the earliest sunset is nearly two weeks before December 22, the days actually growing longer in the afternoon after about December 9, rather than the 22nd. Our latest time of sunset in summer is on July 1, not June 22 and earliest sunrise occurs around June 13 not June 22. Most of these apparent violations of our traditional assumptions as to when these changes occur are caused by the varying equation of time. The time of occurrence of local noon is also affected by equation of time, longitude, location in time zone, and other factors. When daylight savings time is in effect and one is near the edge of a time zone, the crossing of the sun over the observer's meridian (local "noon", as defined by the true sun) may occur nearly two hours after 12 o'clock as read from any local timepiece.

Times of sunrise, sunset and local noon are useful to surveyors, aerial photographers, sportsmen, outdoor athletes in training, and for planning any variety of outdoor activities including Easter sunrise services! Surveyors who travel to other areas and time zones may find information on the sun's behaviour to be useful. At local noon the shadow of a vertical pole points due north, and also the sun has reached its highest altitude for the day. The familiar "hour angle" used in observational astronomy is computed from this reference time and thus knowing the time of local noon is useful to surveyors for estimating the best times for solar hour angle observations for azimuth since such observations should be made at least three hours away from local noon. Likewise, knowing the time of sunrise or sunset is an important aid in planning solar observations in order to avoid problems and have the best observation conditions.

The author has written an HP41 program which computes the time of sunrise, sunset and local noon for any date and for any spot in the world where latitude and longitude can be estimated from a map or globe. Ephemeris tables through 1988 in the author's **Manual of Astronomic and Grid Azimuth** (published by Landmark Enterprises) are a source of other input needed to make the computation. For a free copy of the program send a self-addressed, stamped envelope to Dr. R. B. Buckner, School of Applied Science and Technology, Box 19,060A, East Tennessee State University, Johnson City, TN37614-0002. If anyone wants the program on magnetic card for the HP41, send one blank card.

Professor Buckner is a well-known educator in the United States and he has been very active in ACSM for many years. Professor Buckner is currently at Fast Tennessee State University, Johnson City, Tennessee.