CHAPTER TWO

The Ecliptic Motion of the Sun

There was a time when the apparent motion of the sun, through the sky, was a part of the "common knowledge" of people. We depended upon it for agricultural, religious and time keeping purposes. The advent of the calendar and the time keeping mechanism transferred our dependency from observing the sun to our "watching the clock" and the calendar instead. This transfer caused our "common knowledge" of the sun to slowly slip away. All that seems to remain is that "the sun rises in the east and sets in the west." This happens to be true for only two days out of the year. Very few people realize that the sunrise and sunset points on the horizon change during the course of the year, or that the noon time sun is not directly overhead during most of the summer.

The life of man was at one time greatly structured by the movement of the sun. Early man was of necessity a student of the sun's movement. The sun is still relentlessly following its seasonal cycles for the willing student of today.

The earth rotates 360°, about its axis, in 23 hours, 56 minutes and 4 seconds. At the same time, the earth revolves 360°, around the sun, in 365 1/4 days. The motion called rotating is different from the motion called revolving in that the former motion has an axis within the moving body and the latter motion has an axis that is outside of the moving body.

The west to east rotation of the earth will cause the sun to appear to participate in the apparent diurnal motion of the celestial sphere. The sun will appear to rise in the general direction of east and set in the general direction of west every day.

The counterclockwise revolution of the earth around the sun will cause the sun to appear to move approximately 1° per day, (365.25 days/360°) counterclockwise, from west to east with respect to the stars on the celestial sphere. The apparent, counterclockwise, west to east, motion of revolution of the sun along the celestial sphere is the reflected motion of the earth's counterclockwise revolution around the sun.

The apparent annual motion of the sun, 360° per year, is much slower than the apparent diurnal motion of the sun, 360° per day. The apparent annual motion of the sun from west to east is in the opposition direction to the east to west apparent diurnal motion of the sun.

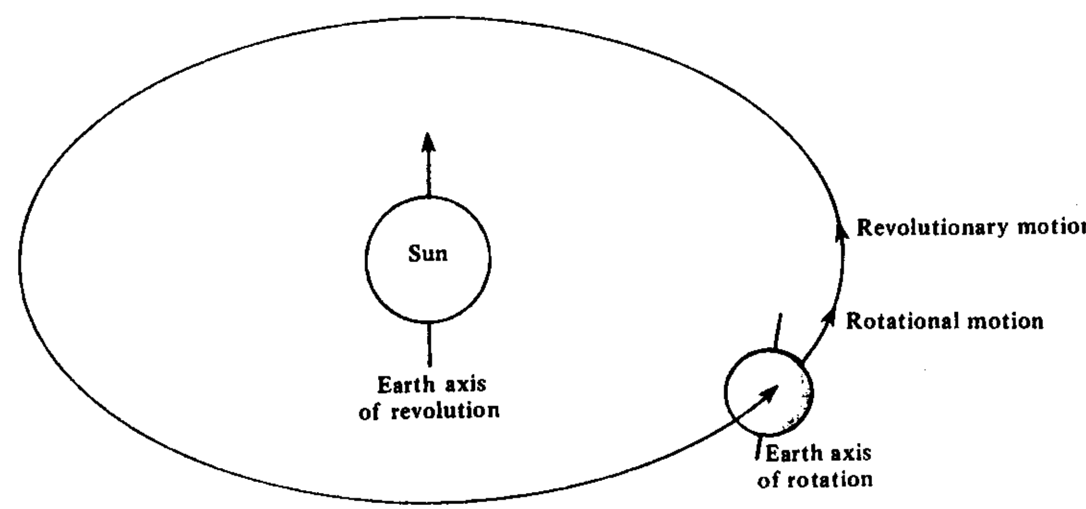


Figure 14. The rotation and revolution of the earth.

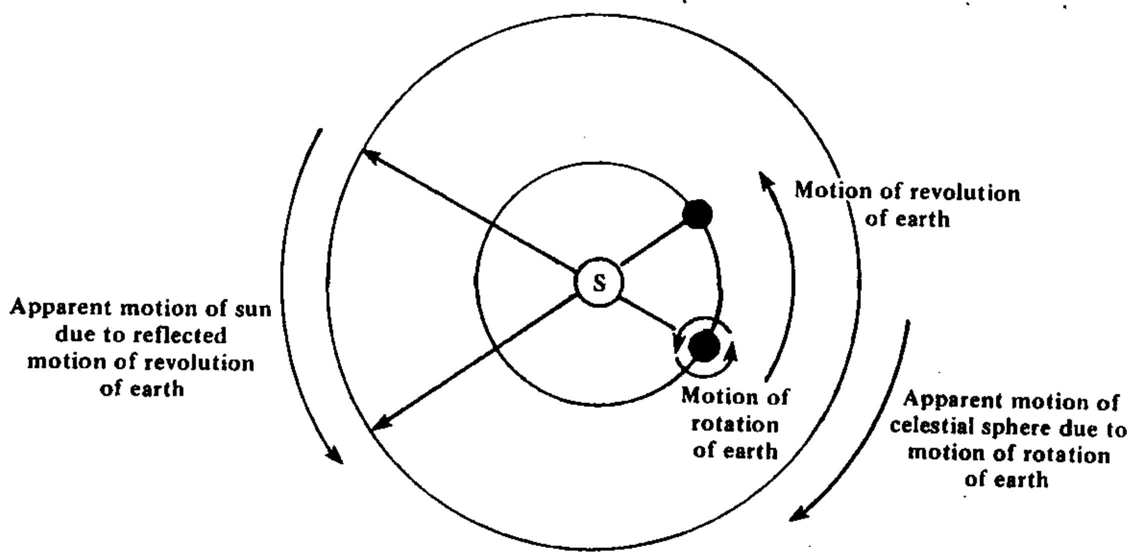


Figure 15. Reflected rotational and revolutionary motion of the earth.

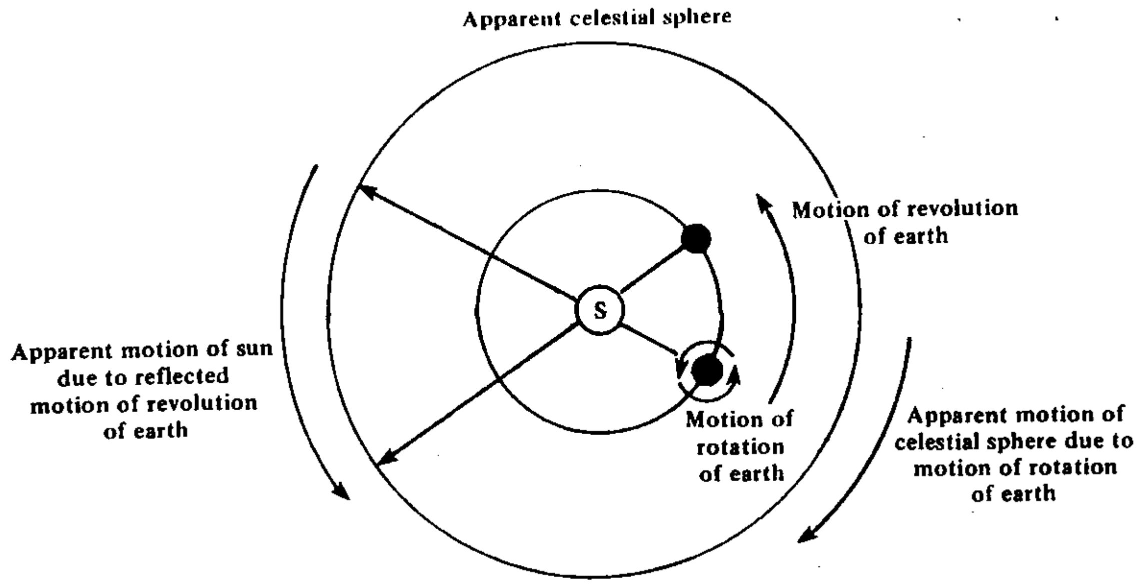
The apparent path of the sun through the fixed stars of the celestial sphere is called the ecliptic. The word ecliptic comes from the Greek word "ekleipsis" which means "being absent". The ecliptic path is the place where eclipses or absenses of the sun and moon take place.

A series of constellations lie along the ecliptic. These constellations comprise the zodiac. The word zodiac comes from the Greek "zodiakos kyklos" which means "circle of animals". Archaic Euphratean astronomy had a zodiac of six constellations—Taurus, Cancer, Virgo, Scorpius, Capricornus and Pisces. These were later divided into twelve constellations because of the annual occurence of twelve full moons in successive parts of the ecliptic. The Babylonians started with eight zodiac constellations then later changed the number to twelve, thirteen, eleven and finally in the 6th century B.C. back to twelve. The Greeks, Romans and later peoples adopted twelve as the final number of zodiac constellations. All zodiac constellations are named after living creatures, with the exception of Libra, the Scales. Table 5 lists the zodiac constellation names, meanings and signs.

TABLE 5
Zodiac Constellations

Constellation Name	(Translation)	Sign
Aries	(Ram)	♈
Pisces	(Fish)	♓
Aquarius	(Water Bearer)	♒
Capricornus	(Sea Goat)	♑
Sagittarius	(Archer)	♐
Scorpius	(Scorpion)	♏
Libra	(Scales)	♎
Virgo	(Virgin)	♍
Leo	(Lion)	♌
Cancer	(Crab)	♋
Gemini	(Twins)	♊
Taurus	(Bull)	♉

The twelve zodiac constellations were originally supposed to represent the monthly motions of the sun through the twelve months of the year. In establishing the zodiac constellations, the Babylonians discovered that the apparent annual



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The twelve zodiac constellations were originally supposed to represent the monthly motions of the sun through the twelve months of the year. In establishing the zodiac constellations, the Babylonians discovered that the apparent annual motion of the sun was uneven. The sun appears to move slightly less than 1° per day near July 4 and slightly more than 1° per day near January 4. From July 4 to January 4 the rate increases from 0° 57′ per day to 1° 01′ per day. From January 4 to July 4 it decreases from 1°01′ per day to 0° 57′ per day. This uneven rate of motion lead to the discovery of the inequality in the lengths of the seasons. The time from the beginning of spring to the beginning of autumn is seven days longer than the time from the beginning of autumn to the beginning of spring.

The apparent movement of the sun through four 90° angles on the celestial sphere constitutes the time length of the four seasons. Table 6 summarizes the data.

TABLE 6

Date	Season Beginning	Day Number in Year	Length of Season
March 21	Spring	80	Spring = 172 − 80 = 92 days
June 21	Summer	172	Summer = 266 − 172 = 94 days
Sept. 23	Autumn	266	Autumn = 356 − 266 = 90 days
Dec. 22	Winter	356	Winter = 455 − 356 = 89 days
March 21	Spring	445 (80+365)	

This, apparently, uneven motion of the sun is a reflection of the earth's uneven motion of revolution around the sun. The earth moves around the sun in an elliptical orbit in such a way that an imaginary line between the sun and the earth sweeps out equal areas of space in equal amounts of time. An ellipse (see Figure 16) is a plane curve such that the sum of the distances from a point on the curve to two fixed points within the curve (foci) is a constant that is equal to the length of the major axis of symmetry of the ellipse. The sun occupies one of the focus points of the earth's elliptical orbit. The second focus point is empty. When the earth is closest to the sun (perihelion position) the distance between the earth and the sun is at a minimum and the earth moves through a greater angular distance in a period of time then it does when the distance between the earth and the sun is at a maximum (aphelion position). This description of the earth's motion around the sun was published by the astronomer Johannes Kepler in 1609.

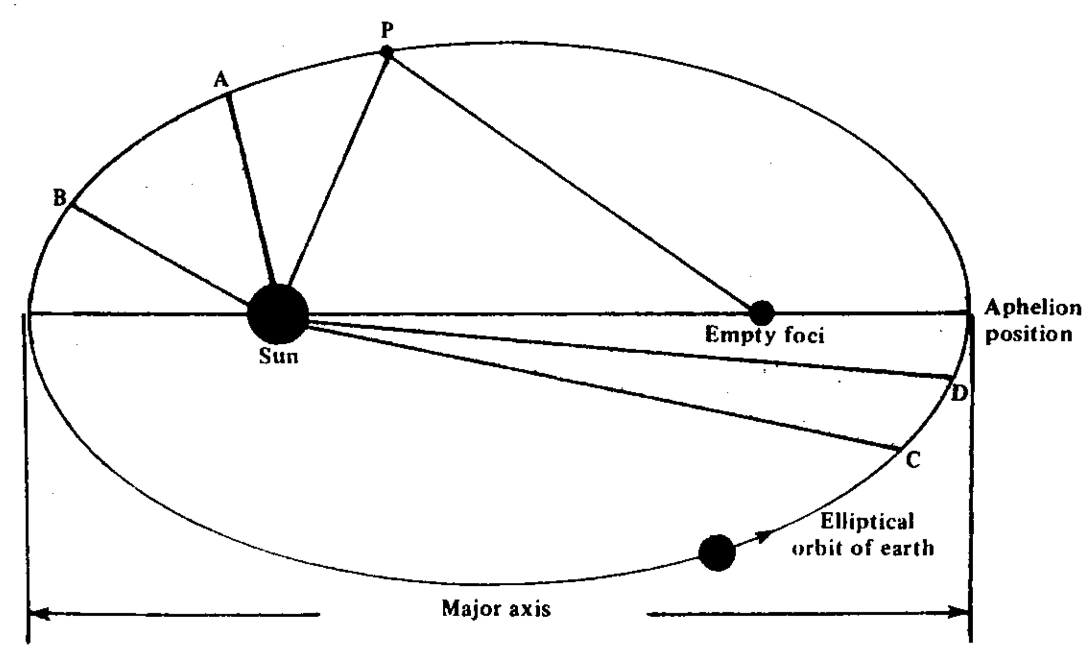


Figure 16. The elliptical orbit of the earth.

The imaginary line between the planet earth and the sun will sweep out equal areas in equal periods of time. The time between A and B is equal to the time between C and D.

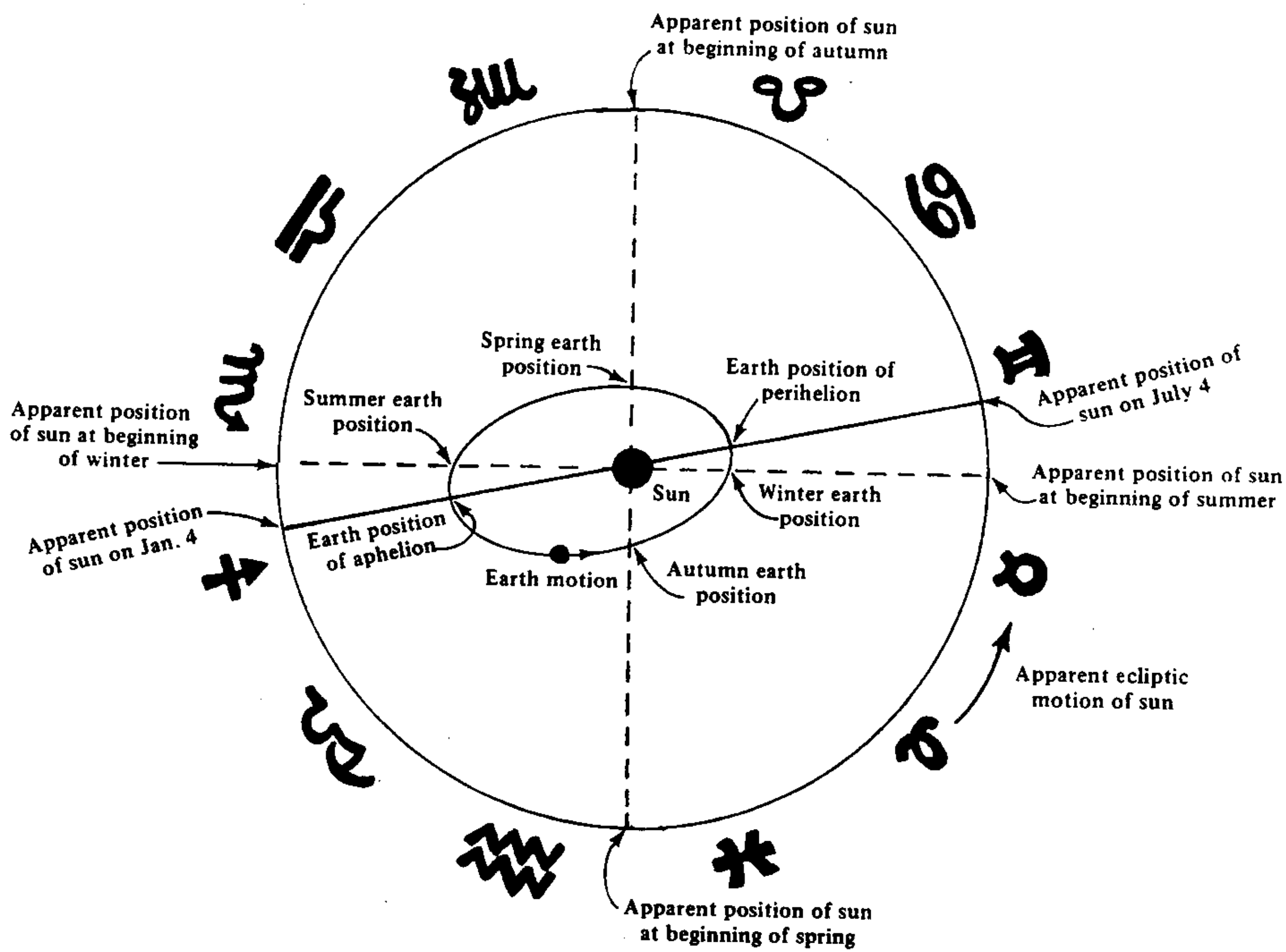


Figure 17. The seasonal motion of the sun through the zodiac.

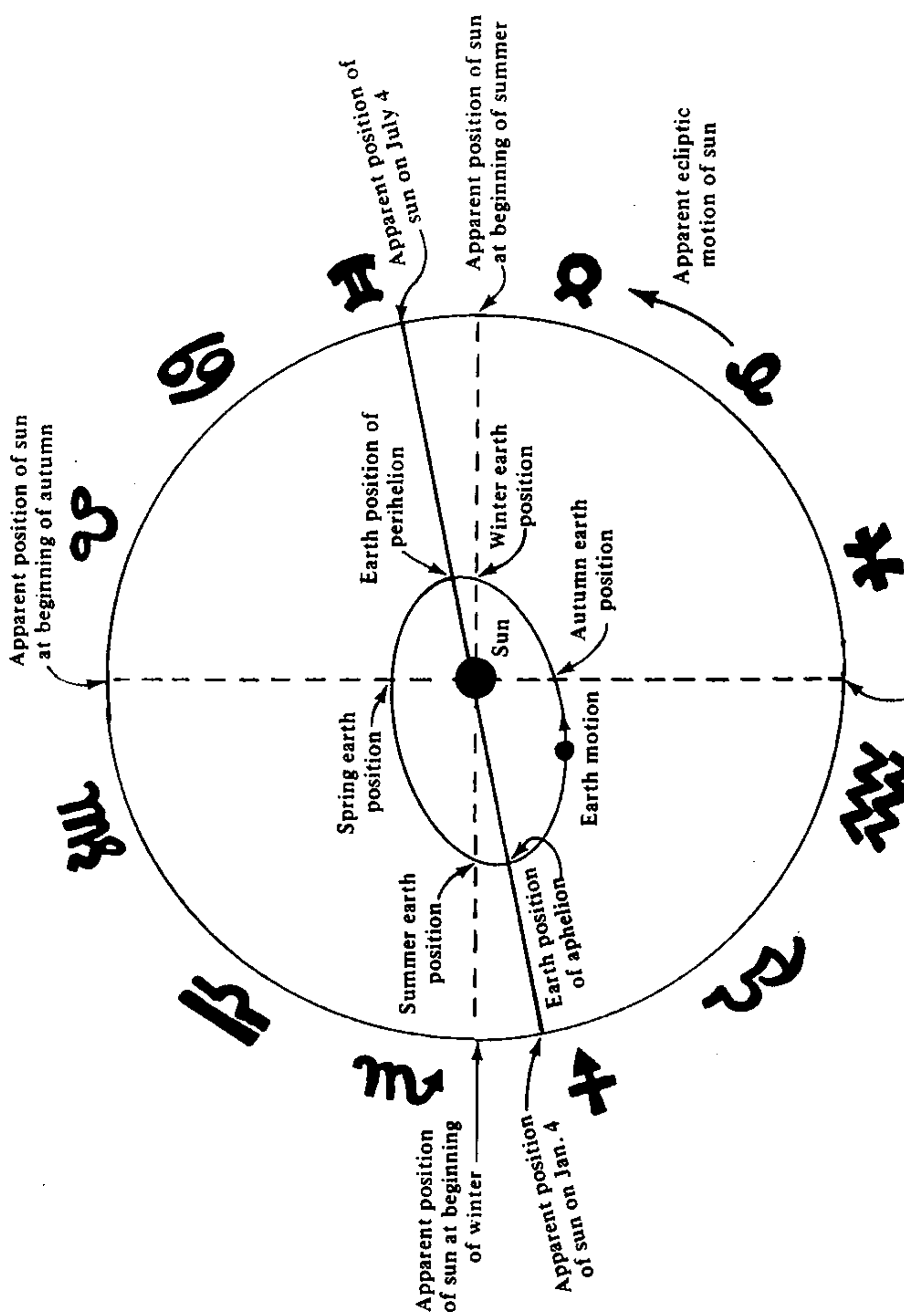


Figure 17. The seasonal motion of the sun through the zodiac.

Therefore the A-sun-B area is equal to the C-sun-D area. Notice the angular distances between AB and CD. The orbit of the earth is an ellipse such that the sum of the distances from both foci to any point on the orbit, P, is equal to the length of the major axis.

The earth's angular rate of motion reaches a maximum around January 4, the time of perihelion. The sun, by reflected motion therefore, appears to be moving through the background stars at its greatest angular rate of 1° 01′ per day around January 4, the time of perihelion. The earth's angular rate of motion reaches a minimum around July 4, the time of aphelion. The sun, by reflected motion therefore, appears to be moving through the background stars at its slowest angular rate of 0°57′ per day around July 4, the time of aphelion. The uneven motion of the earth, which is seen as an apparently uneven motion of the sun through the zodiac constellations, is the cause of the inequality in the lengths of the seasons.

Figure 17 shows the position of the sun at perihelion, aphelion and at the beginning of the four seasons. The figure also illustrates the apparently uneven motion of the sun through the zodiac constellations.

> The word sun is an old Teutonic word. The Greek word for sun is "helios" from which we get the terms: heliocentric system—"sun centered system" and heliotropic—"plants that turn to face the sun". The Latin word for sun is "sol" from which we get the terms: solstice—"sun stop" and solar system—"sun and companions."

You may already know that the earth's rotational axis and revolutionary axis are not aligned in the same space direction. The earth's rotational axis is at an angle of 23 1/2° with respect to the earth's revolutionary axis. This is sometimes referred to as the "tilt" of the earth's axis.

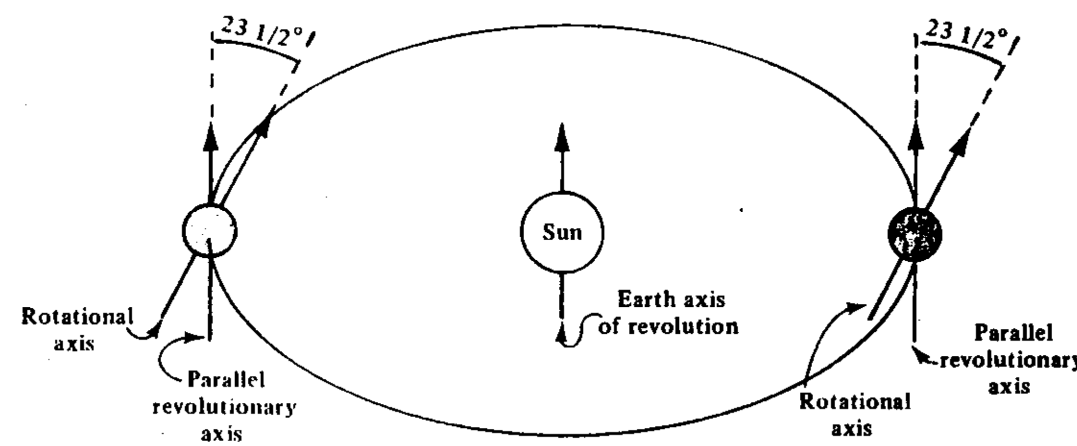


Figure 18. The "tilt" of the earth's rotational axis.

The 23 1/2° angle between the space directions of the earth's rotational axis and revolutionary axis is seen on the celestial sphere as a 23 1/2° angle between the ecliptic plane and the plane of the celestial equator. The ecliptic plane is the plane of the earth's revolutionary motion around the sun. The plane of the celestial equator is the projection of the earth's equatoral plane on to the celestial sphere. Since the revolutionary axis and the rotational axis of the earth have space directions that differ by 23 1/2°, the two planes which are perpendicular to the axes, will also differ by 23 1/2°. This angle is referred to as the "obliquity of the ecliptic." The obliquity of the ecliptic is not a constant, although for most purposes, it can be considered a constant. At present, it amounts to 23°26′54″, but is diminishing about 0.5″ per year. After 1500 years, the angle will start to increase. The maximum deviation amounts to about 1°.5.

Because the ecliptic plane is inclined to the plane of the celestial equator, the sun will appear to cross the celestial equator two times each year and reach maximum angular distances of 23 1/2° above and below the celestial equator once each year. Figure 19 illustrates the ecliptic motion of the sun with respect to the celestial equator. The vernal equinox (green or spring equal-night) is the time and place of the sun's apparent crossing of the celestial equator as the sun moves from *below to above* the celestial equator. The vernal equinox takes place about March 21 each year. The time of the

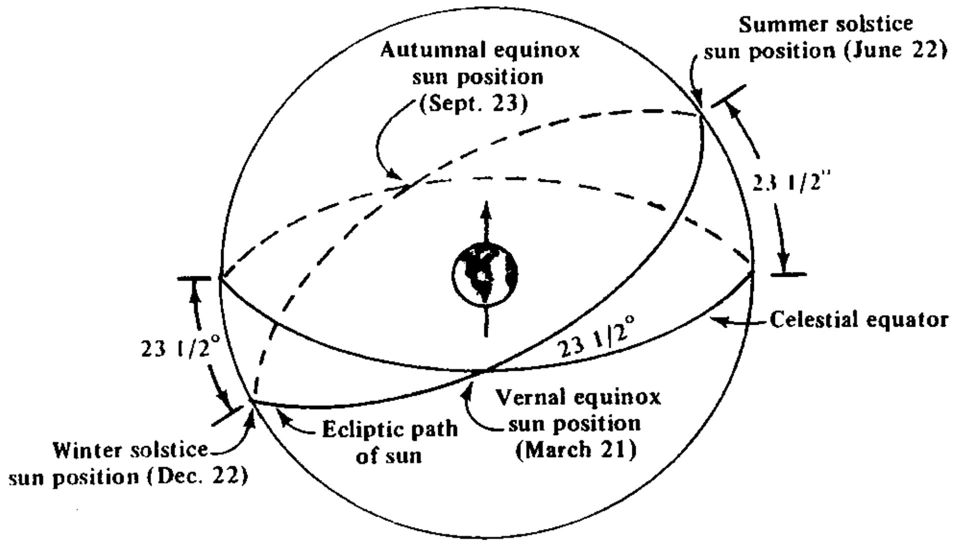


Figure 19. Sun positions on the celestial sphere.

vernal equinox is the time of the official beginning of the spring season. The position of the vernal equinox is at the intersection of the constellations Pisces and Aquarius.

The summer solstice (summer sun-stop) is the time and place of the sun's greatest angular distance (23 1/2°) above the celestial equator. The summer solstice takes place about June 22 each year when the sun reaches an angle of 23 1/2° above the celestial equator. The time of the summer solstice is the time of the official beginning of the summer season. The position of the summer solstice is at the intersection of the constellations Gemini and Taurus.

The autumnal equinox (autumn equal-night) is the time and place of the sun's apparent crossing of the celestial equator as the sun moves from *above to below* the celestial equator. The autumnal equinox takes place about September 23 each year. The time of the autumnal equinox is the time of the official beginning of the autumn season. The position of the autumnal equinox is at the intersection of the constellations Virgo and Leo.

The winter solstice (winter sun-stop) is the time and place of the sun's greatest angular distance (23 1/2°) below the celestial equator. The winter solstice takes place about December 22 each year when the sun reaches an angle of 23 1/2° below the celestial equator. The time of the winter solstice is the time of the official beginning of the winter season. The position of the winter solstice is at the intersection of the constellation Sagitarius and Scorpius.

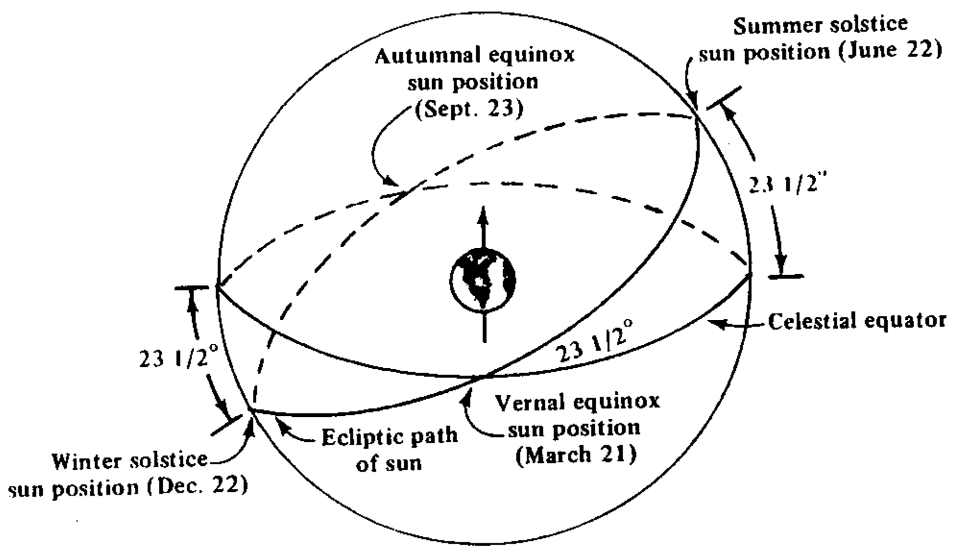
The sun appears to be above the celestial equator from the time of the vernal equinox to the time of the autumnal equinox. The sun appears to be below the celestial equator from the time of the autumnal equinox to the time of the vernal equinox.

At the time and place of the summer solstice the sun appears to be 23 1/2° above the celestial equator and at the time and place of the winter solstice the sun appears to be 23 1/2° below the celestial equator. The sun, therefore, appears to move 47° (2 x 23 1/2°) on the celestial sphere in the north-south direction. The sun moves north from the time and place of the winter solstice (−23 1/2°) to the time and place of the summer solstice (+23 1/2°). The sun moves south from the time and place of the summer solstice (+23 1/2°) to the time and place of the winter solstice (−23 1/2°).

The celestial sphere appears to rotate 360° from east to west in $23^h56^m04^s$. The sun appears to participate in this diurnal motion by appearing to rise in the general direction of east and appearing to set in the general direction of west each day. The sun also appears to have an annual 1° per day motion along the ecliptic from west to east with respect to the stars on the celestial sphere. The sun's annual motion, which is directionally opposite to the diurnal motion, requires that the celestial sphere rotate approximately 361° in order to get the sun to move 360° with respect to a terrestrial observer. Because of the sun's uneven rate of motion along the ecliptic, it will take varying amounts of time for the sun to appear to move 360° with respect to a terrestrial observer. The average time it takes the sun to appear to move 360° is 24 hours. This is the mean solar day.

The celestial sphere will appear to rotate 361° in one 24 hour mean solar day. This means that a star will appear to complete a 360° rotation 3^m56^s earlier each day than the sun.

$$\text{Solar motion time} - \text{Star motion time} = 3^m56^s$$
$$24^h00^m00^s - 23^h56^m04^2 = 3^m56^s$$



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The autumnal equinox (autumn equal-night) is the time and place of the sun's apparent crossing of the celestial equator as the sun moves from *above to below* the celestial equator. The autumnal equinox takes place about September 23 each year. The time of the autumnal equinox is the time of the official beginning of the autumn season. The position of the autumnal equinox is at the intersection of the constellations Virgo and Leo.

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The celestial sphere appears to rotate 360° from east to west in $23^h56^m04^s$. The sun appears to participate in this diurnal motion by appearing to rise in the general direction of east and appearing to set in the general direction of west each day. The sun also appears to have an annual 1° per day motion along the ecliptic from west to east with respect to the stars on the celestial sphere. The sun's annual motion, which is directionally opposite to the diurnal motion, requires that the celestial sphere rotate approximately 361° in order to get the sun to move 360° with respect to a terrestrial observer. Because of the sun's uneven rate of motion along the ecliptic, it will take varying amounts of time for the sun to appear to move 360° is 24 hours. This is the mean solar day.

The celestial sphere will appear to rotate 361° in one 24 hour mean solar day. This means that a star will appear to complete a 360° rotation 3^m56^s earlier each day than the sun.

$$\text{Solar motion time} - \text{Star motion time} = 3^m56^s$$
$$24^h00^m00^s - 23^h56^m04^2 = 3^m56^s$$

AZTEC CALENDAR STONE

The Aztecs had one of the most elaborate and accurate calendars ever developed. The calendar cycle of 52 years was made of 365 days with 18 twenty day "months" and 1 five day "month". The one piece 12 foot diameter stone shows the sun in the center. The four large arrows represent the solstice points and equinox points.

Stars will appear to rise in the general direction of east 3^m56^s earlier each night. They will also appear to set in the general direction of west 3^m56^s earlier each night.

Since the celestial sphere appears to rotate 361° in a 24 hour mean solar day, a star will appear to be 1° farther to the west of its original position after every 24 hour passage of time. Over a period of weeks, at a time of night that is constant, different stars will appear above the eastern horizon and familiar stars will disappear below the western horizon. See Figure 3. This apparent 1° per day, east to west, motion of the stars with respect to a terrestrial observer viewing at a constant time is due entirely to the revolution of the earth around the sun. By continuously viewing at a constant time of day, the earth's rotation will be eliminated as a factor of the observations. The phenomena of the seasonal constellations is due to the revolutionary motion of the earth around the sun.

The sun's apparent ecliptic motion will systematically change the noon time altitude of the sun for all terrestrial observers. Since the ecliptic is inclined 23 1/2° to the celestial equator, a terrestrial observer will view the sun to be 23 1/2° above the celestial equator-meridian intersection point at the time of the summer solstice (June 22) and 23 1/2° below the celestial equator-meridian intersection point at the time of the winter solstice (December 22). At the times of the equinox points, the sun will cross the observer's meridian around noon at the same angular height above the southern horizon as the celestial equator. The total angular variation is 47°. Figure 20 graphically illustrates the systematic variation of the angular displacement of the sun with respect to the celestial equator at the transit or crossing of the meridian.

The noon sun will increase its angular height above the southern horizon from the time of the winter solstice until the time of the summer solstice. The noon sun will decrease its angular height above the southern horizon from the time

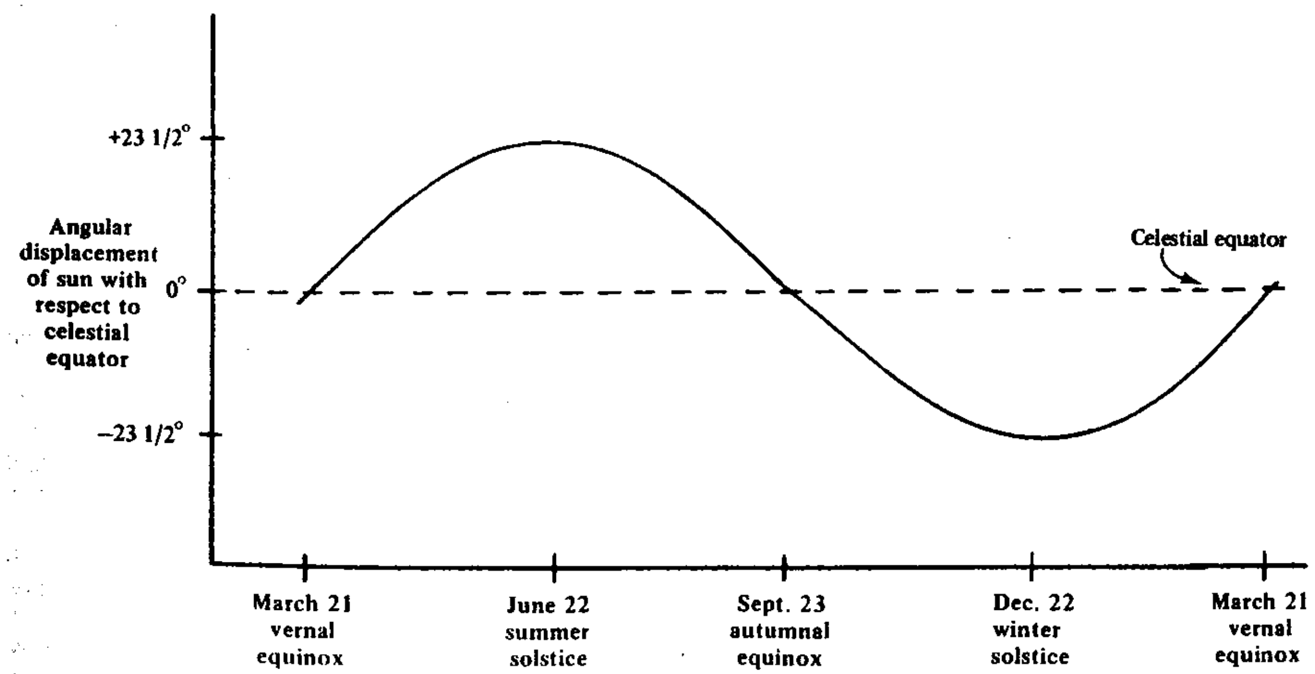

Figure 20. Systematic variation in meridian transit of sun.

of the summer solstice to the time of the winter solstice. The word solstice means "sun-stop." It refers to the time that the sun stops increasing or decreasing its angular height on the observer's meridian above the southern horizon.

The sun's rate of ascent and descent along the meridian, at the time of transit systematically changes during the year according to the angle between the sun's ecliptic path and a line parallel to the celestial equator. When the sun is near the equinox points, it is moving at an angle of 23 1/2° to the celestial equator and moves approximately .38° in the north or south direction. This is the maximum daily change in the angular height of the meridian sun above the southern horizon. When the sun is near the solstice points, it is moving almost parallel to the celestial equator and moves hardly at all in the north or south direction. This is the "sun stop" position. Figure 21 shows the north-south movement of the meridian sun at the equinox and solstice positions. Figure 22 graphically illustrates the systematic variation the daily rate of north-south movement of the meridian sun during the year.

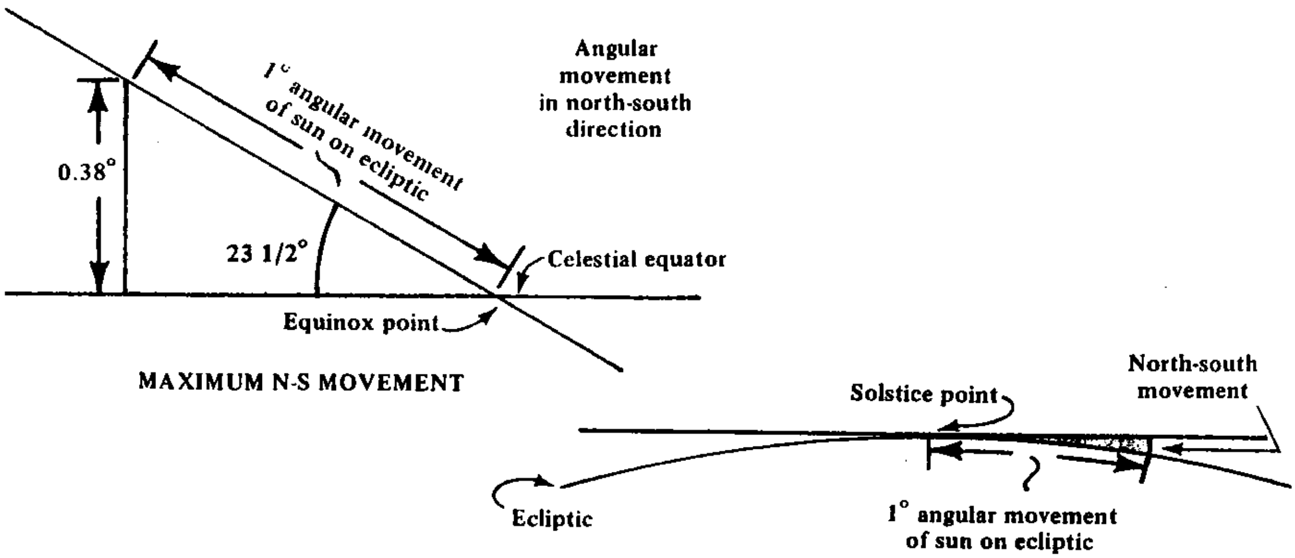

Figure 21. Maximum and minimum north-south motion of meridian sun.

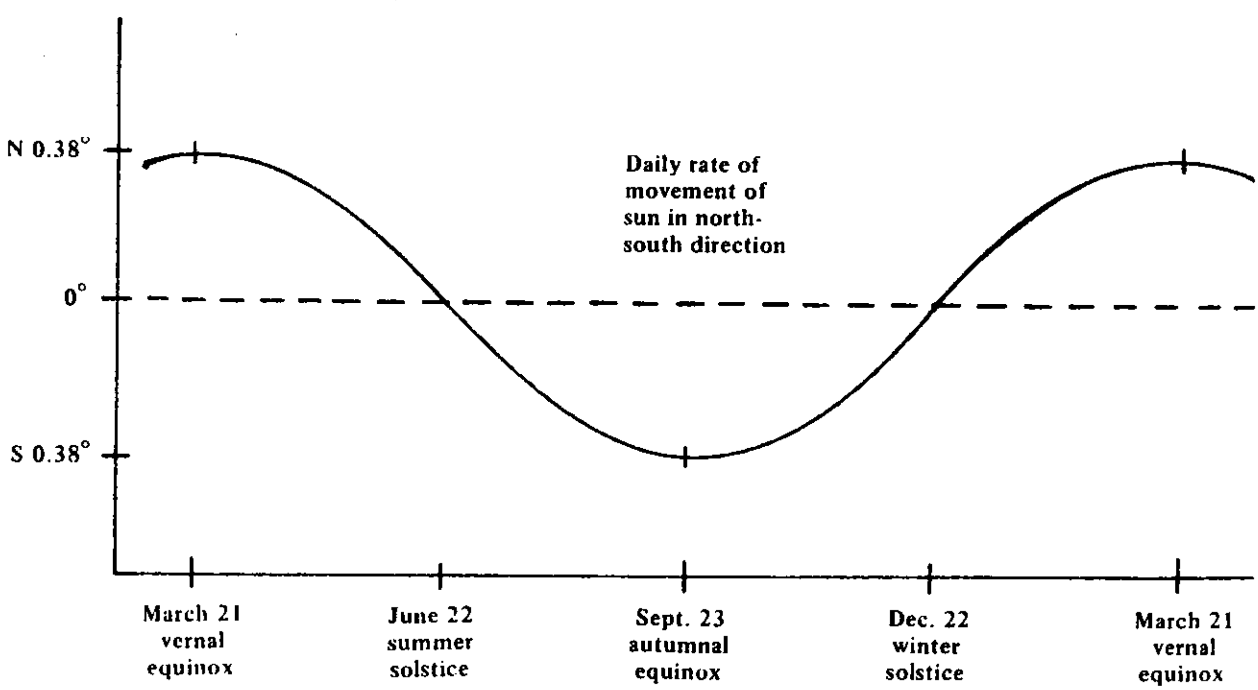

Figure 22. Systematic variation in daily rate of north-south motion of meridian sun.

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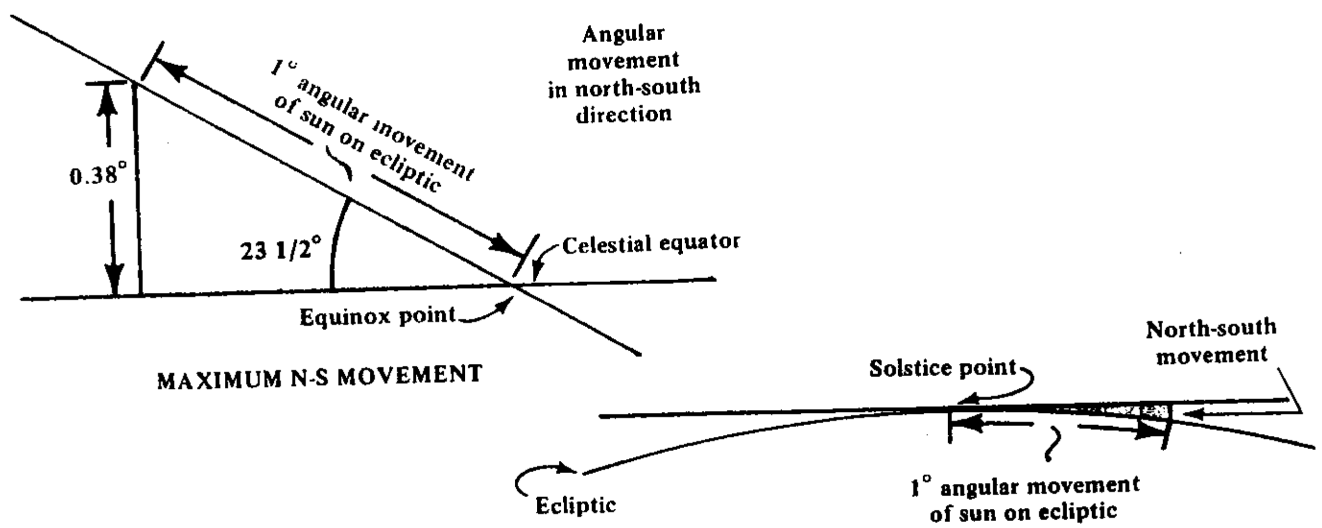

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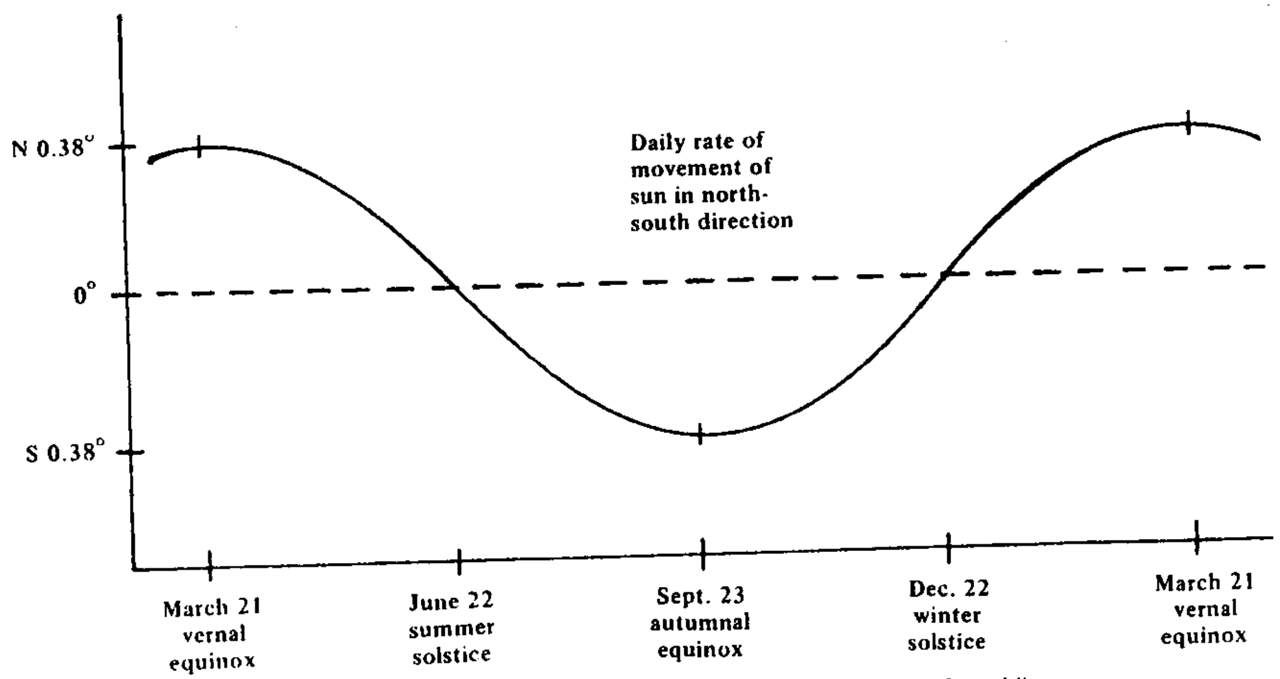


Figure 22. Systematic variation in daily rate of north-south motion of meridian sun.

The position on the observer's horizon where the sun will appear to rise and set will also systematically vary due to the sun's apparent ecliptic motion. The angular displacement between the summer solstice sunset position and the winter solstice sunset position is determined by the angle at which the celestial equator meets the due west point on the observer's horizon. This angle is determined by the observer's geocentric latitude.

If the celestial equator makes an angle of 90° with the observer's horizon, the sun will set 23 1/2° to the north of due west on the day of the summer solstice and it will set 23 1/2° to the south of due west on the day of the winter solstice. The maximum angular variation in the sunset position will be 47°. See Figure 23.

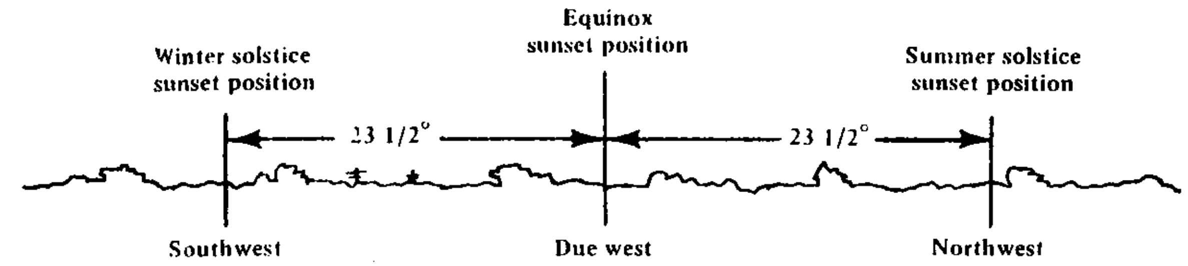


Figure 23. Sunset variation at latitude 0°.

As the angle between the celestial equator and the observer's horizon decreases, the angular variation in the sunset position will increase. The 23 1/2° angle between the celestial equator and the ecliptic will be projected on the horizon as a larger angle. See Figure 24.

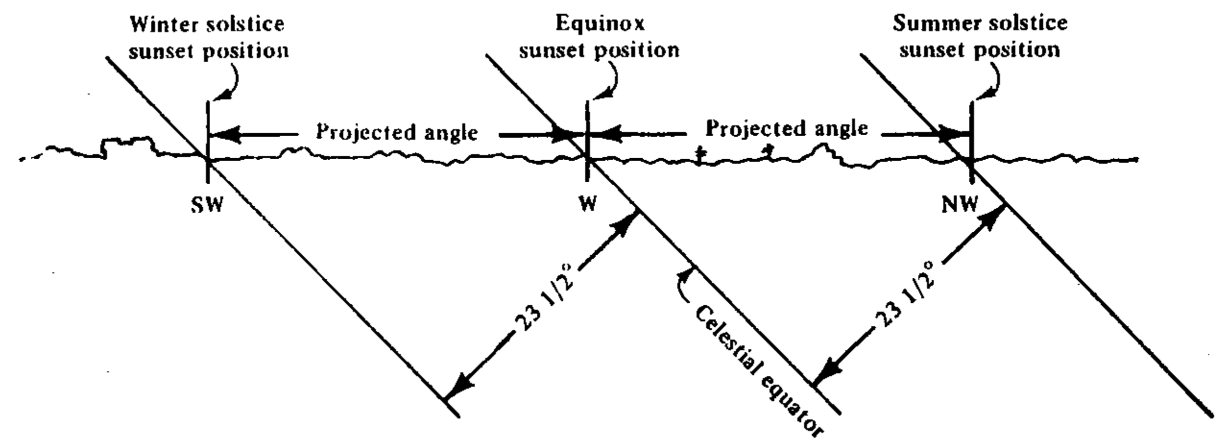


Figure 24. Projected angle of sunset variation.

The sunrise position varies in the same manner as the observer's sunset position. As the latitude of the observer increases the celestial equator-horizon angle decreases and the angular separation between the solstice sunrise and sunset points increases. Eventually a latitude will be reached where the solstice sunrise position meets the solstice sunset position in the due north and south directions. At the time of the summer solstice the sun will remain above the horizon for twenty four hours. At the time of the winter solstice the sun will remain below the horizon for twenty four hours. At higher latitudes the sun will remain above and below the horizon for periods of time greater than twenty four hours. Those latitudes, where the sun is visible for a 24 hour period, are referred to as the "lands of the midnight sun".

The sunrise and sunset positions along the observer's horizon systematically change according to the angle between the sun's changing ecliptic position and the celestial equator. When the sun is near the equinox points it is moving at an angle of 23 1/2° to the celestial equator and making its maximum angular change perpendicular to the celestial equator. This causes the sunrise and sunset positions to make their maximum daily angular change on the observer's horizon. When the sun is near the solstice points, it is moving almost parallel to the celestial equator and moves hardly at all in a direction perpendicular to the celestial equator. This causes the sunrise and sunset positions to make their minimum daily angular change on the observer's horizon.

The sunrise and sunset positions are at a maximum angular displacement to the south of east and west at the time of the winter solstice. Slowly at first, but with increasing speed they begin to move north. At the time of the vernal equinox they are at the due east and due west points, moving northward, and making their maximum daily angular changes along the horizon. The rate of angular displacement of the sunrise and sunset positions decreases at the time of the summer solstice. The sunrise and sunset positions are at a maximum angular displacement to the north of east and west at the time of the summer solstice. At the time of the autumnal equinox they are at the due east and west points, moving southward and making their maximum daily angular changes along the horizon. The rate of angular displacement in the sunrise and sunset positions decrease as the time of the winter solstice is approached. They will once again be their maximum angular displacement to the south of east and west at the time of the winter solstice. It can again be seen that the solstice points are "sun-stop" points.

The length of time that the sun is above the horizon (daytime) and below the horizon (nighttime) will also systematically vary due to the sun's apparent ecliptic motion and the latitude of the observer. The length of daytime depends on the amount of time the sun is above the observer's horizon as it moves in diurnal motion.

The following discussion concerns mid-latitudes in the northern hemisphere. At the time of the winter solstice, when the sunrise and sunset positions are at their maximum angular displacement south of east and west, the sun will be visible above the horizon as it moves through a small arc. This will be the shortest day of the year since for most of the day the sun will be below the horizon. At the time of the equinoxes, the sun rises due east and sets due west. The sun will be above the horizon for half of the day and below the horizon for half of the day. Equinox means equal night. At the time of the summer solstice, when the sunrise and sunset positions are at their maximum angular displacement north of east and west, the sun will be visible above the horizon as it moves through a large arc. This will be the longest day of the year since for most of this day the sun will be above the horizon. Figure 25 shows the relative sun arcs for the equinox and solstice points.

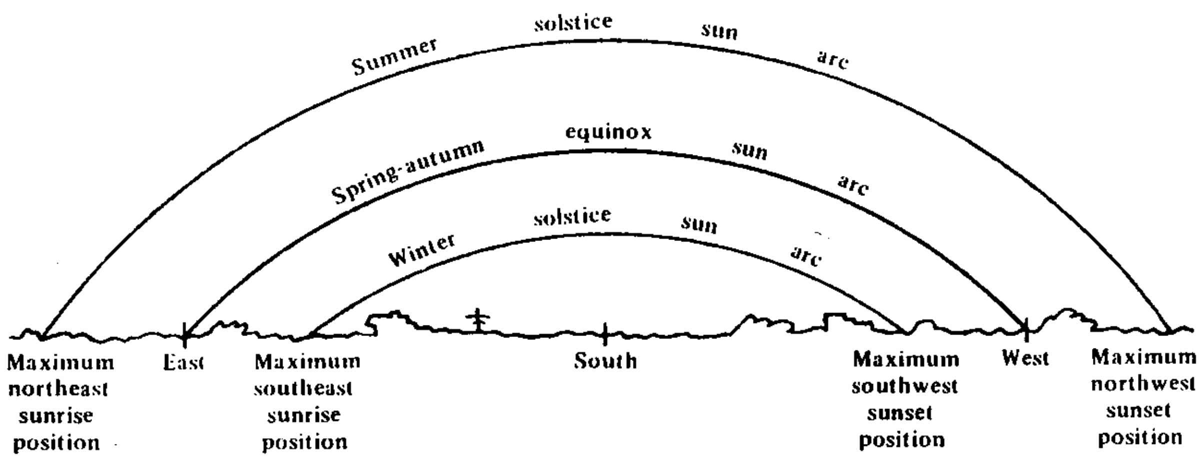


Figure 25. Sun arc and length of day.

The length of the day increases from the time of the winter solstice to the time of the summer solstice and decreases from the time of the summer solstice to the time of the winter solstice. At the latitude where the solstice sunrise positions meet the solstice sunset positions in the due north and south directions, days of total light and total darkness will begin to be possible.

The rate at which the length of daytime changes is dependent upon the angle between the sun's ecliptic motion and the celestial equator. When the sun is near the equinox points it is moving at an angle of 23 1/2° with respect to the celestial equator and making maximum angular changes in its noon time altitude and sunrise and sunset positions. These changes will cause the arc path of the sun above the horizon and therefore the length of day to change by maximum amounts. When the sun is near the solstice points, it is moving almost parallel to the celestial equator and the changes in the noon time altitude and sunrise and sunset points are at a minimum. These changes will cause the arc path of the sun above the horizon and therefore the length of day to change by minimum amounts.

After the time of the winter solstice the days will slowly begin to get longer. Maximum increasing changes in the length of the day will occur at the time of the vernal equinox. The length of the day will continue to increase, but by decreasing amounts, until the time of the summer solstice. The length of the day will stop increasing at the time of the

The sunrise and sunset positions are at a maximum angular displacement to the south of east and west at the time of the winter solstice. Slowly at first, but with increasing speed they begin to move north. At the time of the vernal equinox they are at the due east and due west points, moving northward, and making their maximum daily angular changes along the horizon. The rate of angular displacement of the sunrise and sunset positions decreases at the time of the summer solstice. The sunrise and sunset positions are at a maximum angular displacement to the north of east and west at the time of the summer solstice. At the time of the autumnal equinox they are at the due east and west points, moving southward and making their maximum daily angular changes along the horizon. The rate of angular displacement in the sunrise and sunset positions decrease as the time of the winter solstice is approached. They will once again be their maximum angular displacement to the south of east and west at the time of the winter solstice. It can again be seen that the solstice points are "sun-stop" points.

The length of time that the sun is above the horizon (daytime) and below the horizon (nighttime) will also systematically vary due to the sun's apparent ecliptic motion and the latitude of the observer. The length of daytime depends on the amount of time the sun is above the observer's horizon as it moves in diurnal motion.

The following discussion concerns mid-latitudes in the northern hemisphere. At the time of the winter solstice, when the sunrise and sunset positions are at their maximum angular displacement south of east and west, the sun will be visible above the horizon as it moves through a small arc. This will be the shortest day of the year since for most of the day the sun will be below the horizon. At the time of the equinoxes, the sun rises due east and sets due west. The sun will be above the horizon for half of the day and below the horizon for half of the day. Equinox means equal night. At the time of the summer solstice, when the sunrise and sunset positions are at their maximum angular displacement north of east and west, the sun will be visible above the horizon as it moves through a large arc. This will be the longest day of the year since for most of this day the sun will be above the horizon. Figure 25 shows the relative sun arcs for the equinox and solstice points.

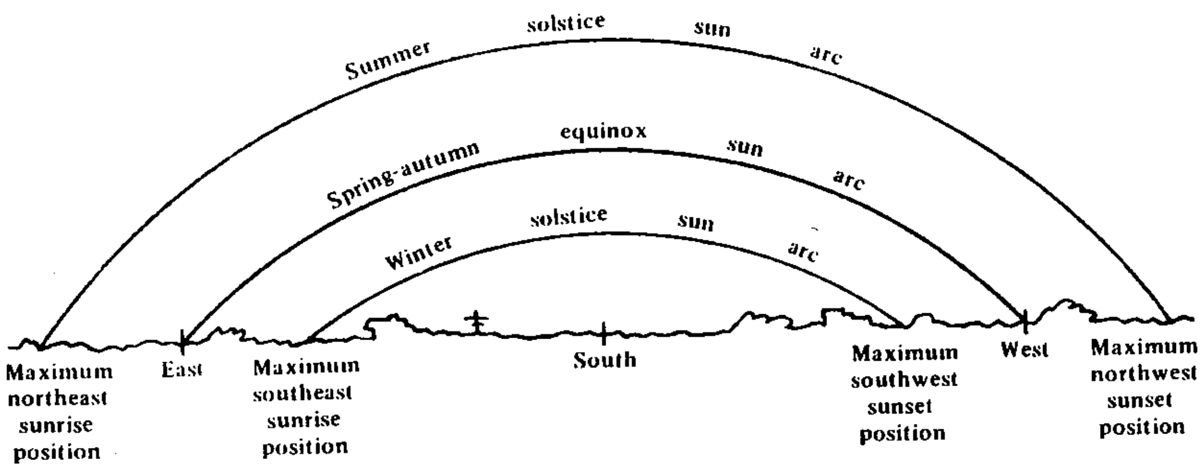


Figure 25. Sun arc and length of day.

The length of the day increases from the time of the winter solstice to the time of the summer solstice and decreases from the time of the summer solstice to the time of the winter solstice. At the latitude where the solstice sunrise positions meet the solstice sunset positions in the due north and south directions, days of total light and total darkness will begin to be possible.

The rate at which the length of daytime changes is dependent upon the angle between the sun's ecliptic motion and the celestial equator. When the sun is near the equinox points it is moving at an angle of 23 1/2° with respect to the celestial equator and making maximum angular changes in its noon time altitude and sunrise and sunset positions. These changes will cause the arc path of the sun above the horizon and therefore the length of day to change by maximum amounts. When the sun is near the solstice points, it is moving almost parallel to the celestial equator and the changes in the noon time altitude and sunrise and sunset points are at a minimum. These changes will cause the arc path of the sun above the horizon and therefore the length of day to change by minimum amounts.

After the time of the winter solstice the days will slowly begin to get longer. Maximum increasing changes in the length of the day will occur at the time of the vernal equinox. The length of the day will continue to increase, but by decreasing amounts, until the time of the summer solstice. The length of the day will stop increasing at the time of the

summer sun stop. After the time of the summer solstice the days will slowly begin to get shorter. Maximum decreasing changes in the length of the day will occur at the time of the autumnal equinox. The length of the day will continue to decrease, but by decreasing amounts, until the time of the winter solstice. The length of the day will stop decreasing at the time of the winter sun stop.

At latitude 0°, the terrestrial equator, the celestial equator will cross the observer's meridian at the zenith point. At the time of the winter solstice the noon time sun will be 23 1/2° below the celestial equator or 66 1/2° above the southern horizon. The sunrise and sunset positions will be 23 1/2° south of the due east and due west points. Sunrise and sunset, for the purposes of this discussion, will be measured by the horizon passage of the center of the sun. At the time of the summer solstice the noon time sun will be 23 1/2° above the celestial equator, 113 1/2° above the southern horizon or 66 1/2° above the northern horizon. The sunrise and sunset positions will be 23 1/2° north of the due east and due west points. At the times of the equinoxes, the noon sun will reach its maximum altitude and pass through the observer's zenith. Since the P_n and P_s points are on the horizon the sun will always move in an arc that is inclined by 90° to the horizon. This means that it will be above the horizon 12 hours and below the horizon 12 hours independent of its ecliptic position and all days and nights will be of the same constant length. Figures 26 and 27 illustrate the motion of the sun as observed from Latitude 0°.

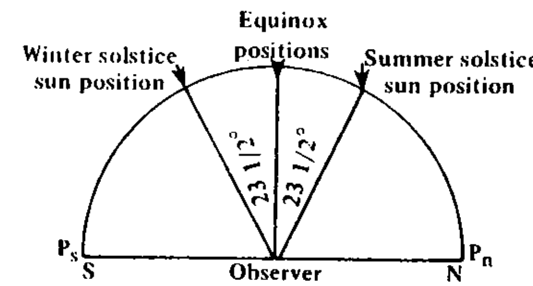


Figure 26. Sun positions from 0° latitude.

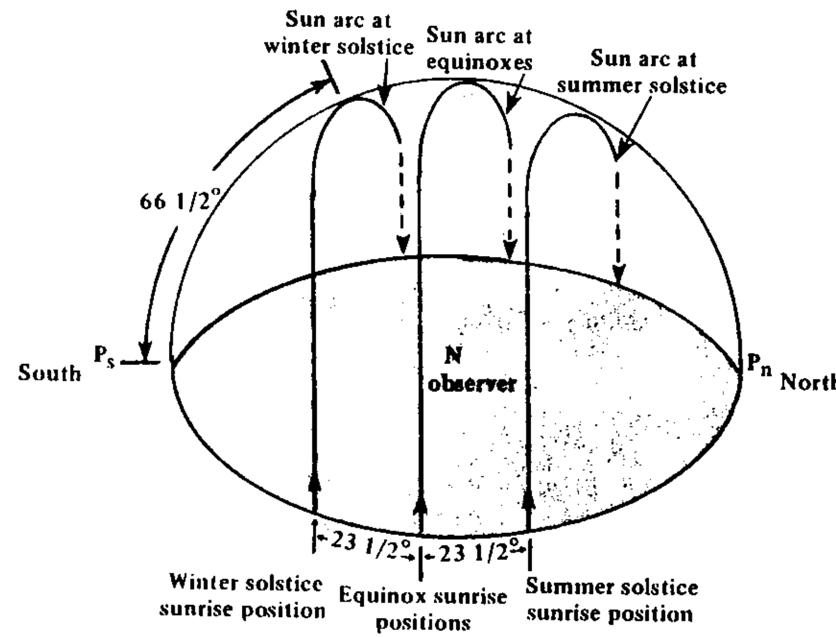


Figure 27. Sun movement from 0° latitude.

At latitude 23 1/2° N, the celestial equator will cross the observer's meridian at an angle of 66 1/2° above the southern horizon. At the time of the winter solstice, the noon time sun will be 23 1/2° below the celestial equator or 43° above the southern horizon. The sunrise and sunset positions will be approximately 26° south of the due east and due west points. This will be the shortest day of the year at this latitude. The sun will be above the horizon approximately 10.5 hours and below the horizon approximately 13.5 hours.

At the time of the summer solstice, the noon time sun will be 23 1/2° above the celestial equator or 90° above the southern horizon. This will be the last latitude in the northern hemisphere to ever have the sun pass through the zenith position. This latitude was designated as the Tropic of Cancer by the Greek Eratosthenes in 3rd century B.C., because the sun was in the constellation Cancer at this time. The sunrise and sunset points will be approximately 26° north of the due east and due west positions. This will be the longest day of the year at this latitude. The sun will be above the horizon approximately 13.5 hours and below the horizon approximately 10.5 hours.

At the times of the equinoxes, the sun will rise due east, reach a maximum noontime altitude of 66 1/2° above the southern horizon, and set due west. Day and night will be of equal length. Figures 28 and 29 illustrate the motion of the sun as observed from latitude 23 1/2°N, the Tropic of Cancer.

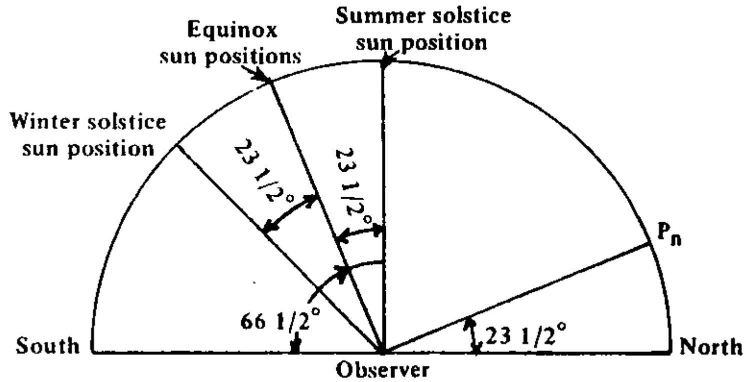


Figure 28. Sun positions from 23 1/2° north latitude.

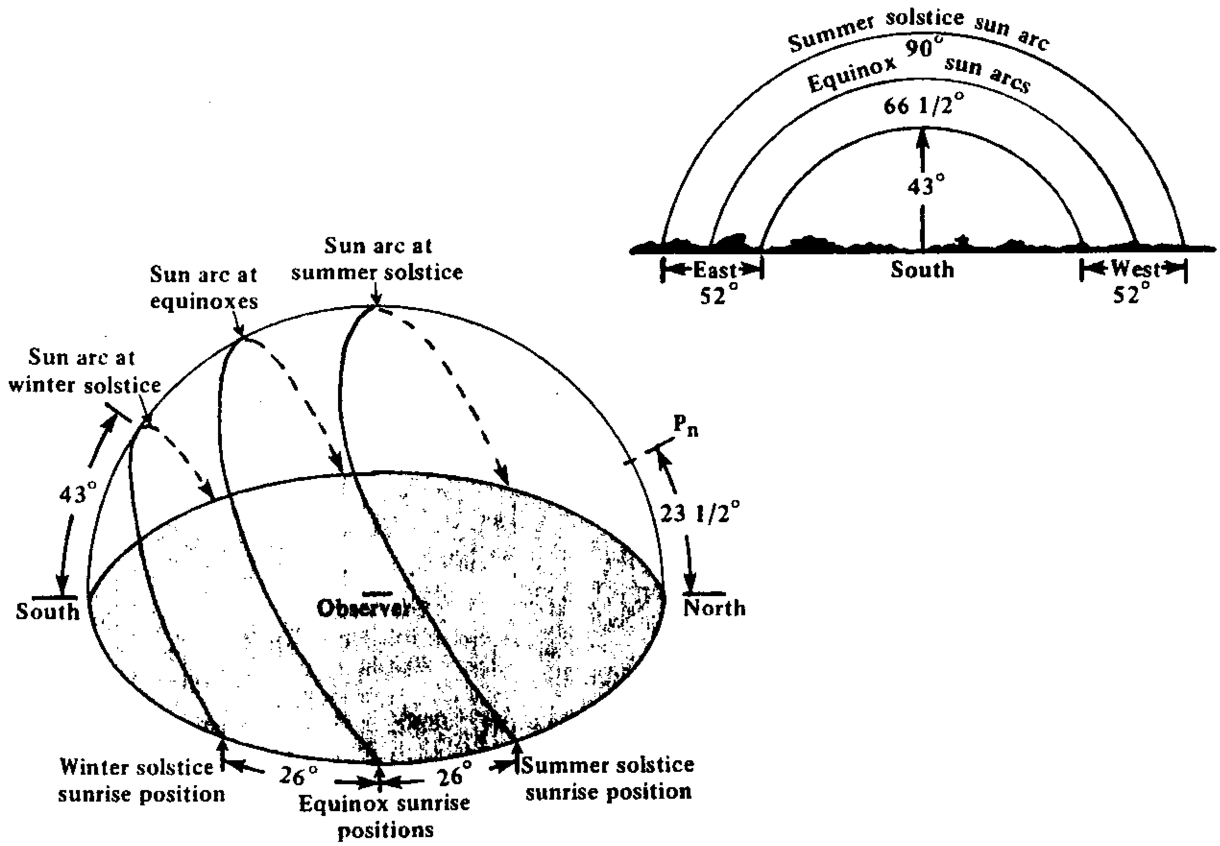


Figure 29. Sun movement from 23 1/2° north latitude.

At the time of the summer solstice, the noon time sun will be 23 1/2° above the celestial equator or 90° above the southern horizon. This will be the last latitude in the northern hemisphere to ever have the sun pass through the zenith position. This latitude was designated as the Tropic of Cancer by the Greek Eratosthenes in 3rd century B.C., because the sun was in the constellation Cancer at this time. The sunrise and sunset points will be approximately 26° north of the due east and due west positions. This will be the longest day of the year at this latitude. The sun will be above the horizon approximately 13.5 hours and below the horizon approximately 10.5 hours.

At the times of the equinoxes, the sun will rise due east, reach a maximum noontime altitude of 66 1/2° above the southern horizon, and set due west. Day and night will be of equal length. Figures 28 and 29 illustrate the motion of the sun as observed from latitude 23 1/2°N, the Tropic of Cancer.

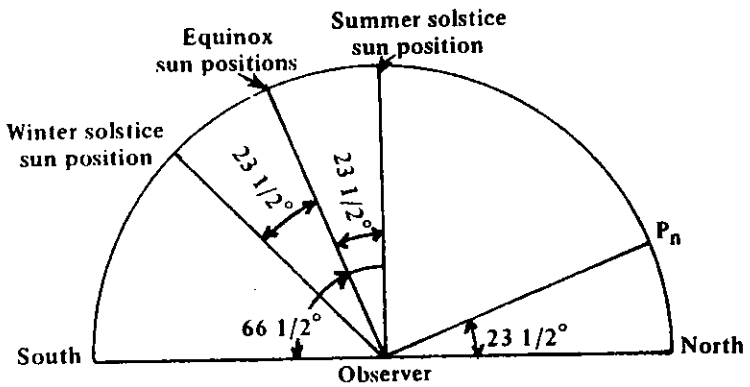


Figure 28. Sun positions from 23 1/2° north latitude.

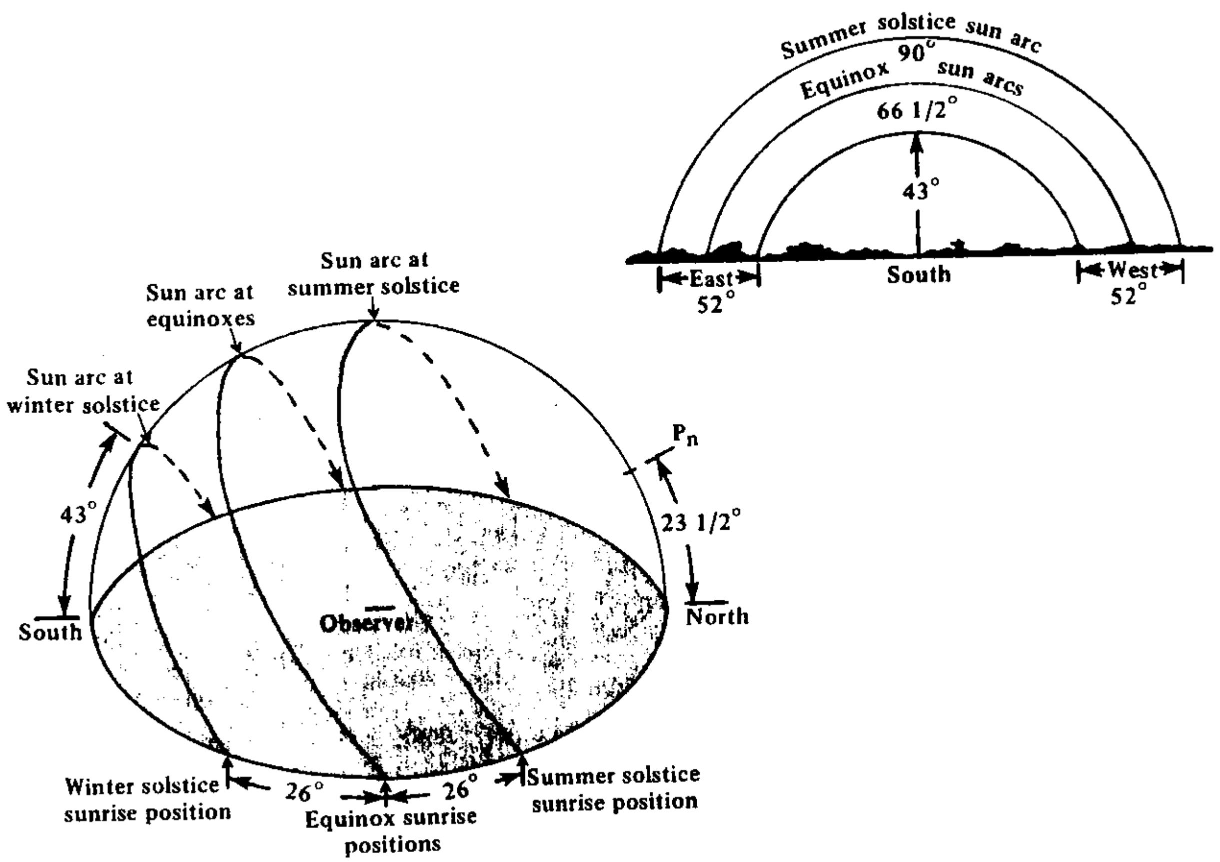


Figure 29. Sun movement from 23 1/2° north latitude.

The longest day at any latitude will take place on the day when the sun reaches its highest altitude. Between the equator and the Tropic of Cancer the longest day will occur on the days when the meridian altitude of the sun is 90°. As the latitude of an observer is increased from 0° latitude, the day, in the first half of the year, when the noon sun reaches 90°, will move back toward the summer solstice date. The day, in the second half of the year, when the noon sun reaches 90°, will also move back toward the summer solstice date. At latitude 23 1/2° N, the two "longest days" meet and only one day is observed as the longest day of the year.

At latitude 40° N, the celestial equator will cross the observer's meridian at an angle of 50° above the southern horizon. At the time of the winter solstice, the noon time sun will be 23 1/2° below the celestial equator or 26 1/2° above the southern horizon. The sunrise and sunset positions will be approximately 31° south of the due east and due west points. This will be the shortest day of the year at this latitude. The sun will be above the horizon approximately 9 hours and below the horizon approximately 15 hours.

At the time of the summer solstice, the noon time sun will be 23 1/2° above the celestial equator or 73 1/2° above the southern horizon. The sunrise and sunset positions will be 31° north of the due east and west points. This will be the longest day of the year at this latitude. The sun will be above the horizon approximately 15 hours and below the horizon approximately 9 hours.

At the times of the equinoxes, the sun will rise due east, reach a maximum noon time altitude of 50° above the southern horizon, and set due west. Day and night will be of equal length. Figures 30 and 31 illustrate the motion of the sun as observed from latitude 40° north.

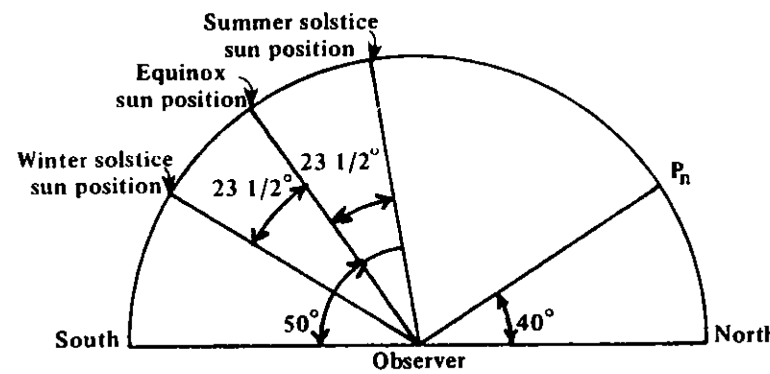


Figure 30. Sun positions from 40° north latitude.

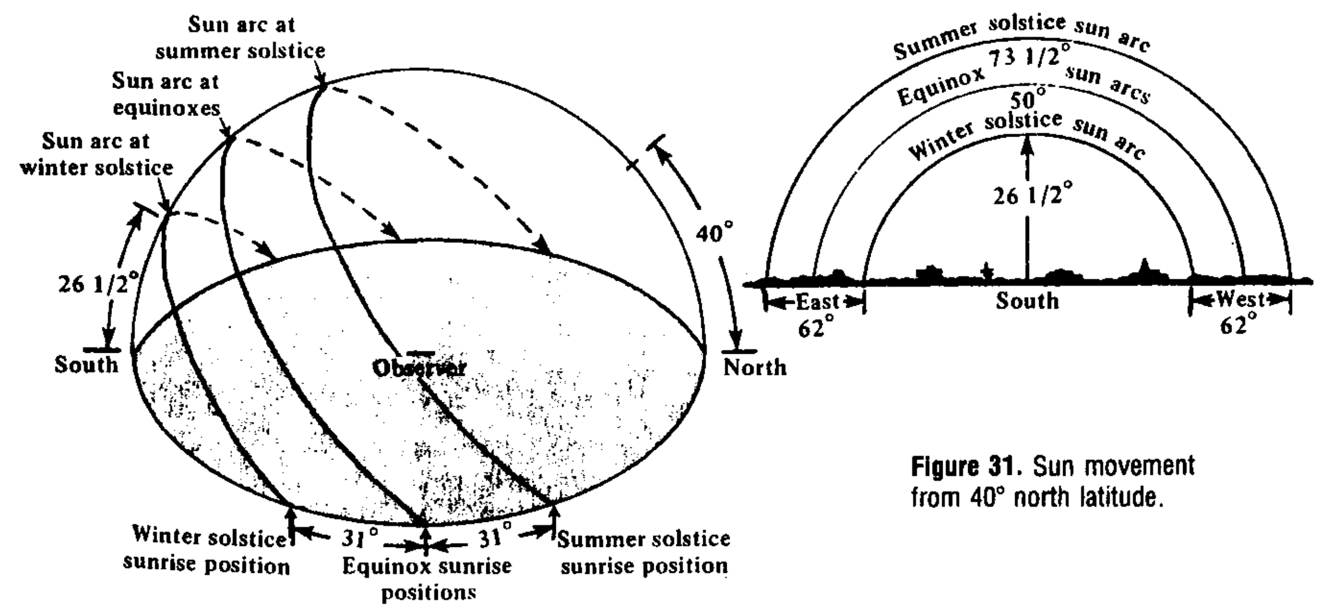


Figure 31. Sun movement from 40° north latitude.

At latitude 66 1/2° N, the celestial equator will cross the observer's meridian at an angle of 23 1/2° above the southern horizon. At the time of the winter solstice, the noon time sun will be 23 1/2° below the celestial equator and at the due south position on the observer's horizon. The sunrise and sunset positions will have moved 90° to the south of the due east and due west points. Since the sunrise and sunset positions coincide, the sun will not totally appear above the horizon on this day. This will be the shortest day of the year at this latitude. The sun will remain below the horizon for 24 hours.

At the time of the summer solstice, the noon time sun will be 23 1/2° above the celestial equator or 47° above the southern horizon. The sunrise and sunset positions will have moved 90° to the north of the due east and due west points. Since the sunrise and sunset positions coincide, the sun will not totally disappear below the horizon on this day. This will be the longest day of the year at this latitude. The sun will remain above the horizon for 24 hours. This latitude begins the "land of the midnight sun."

At the times of the equinoxes, the sun will rise due east, reach a maximum noontime altitude of 23 1/2° above the southern horizon, and set due west. Day and night will be of equal length. Figures 32 and 33 illustrate the motion of the sun as observed from latitude 66 1/2° N.

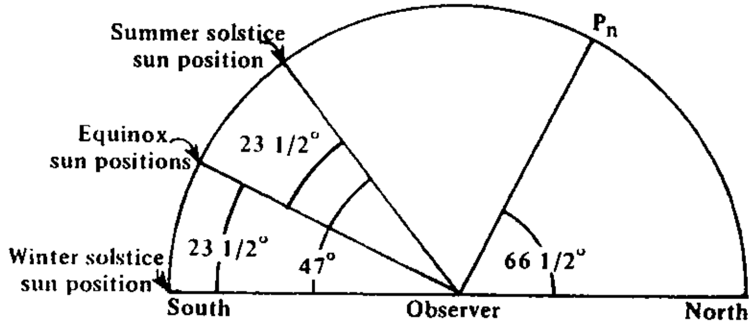


Figure 32. Sun position from 66 1/2° north latitude.

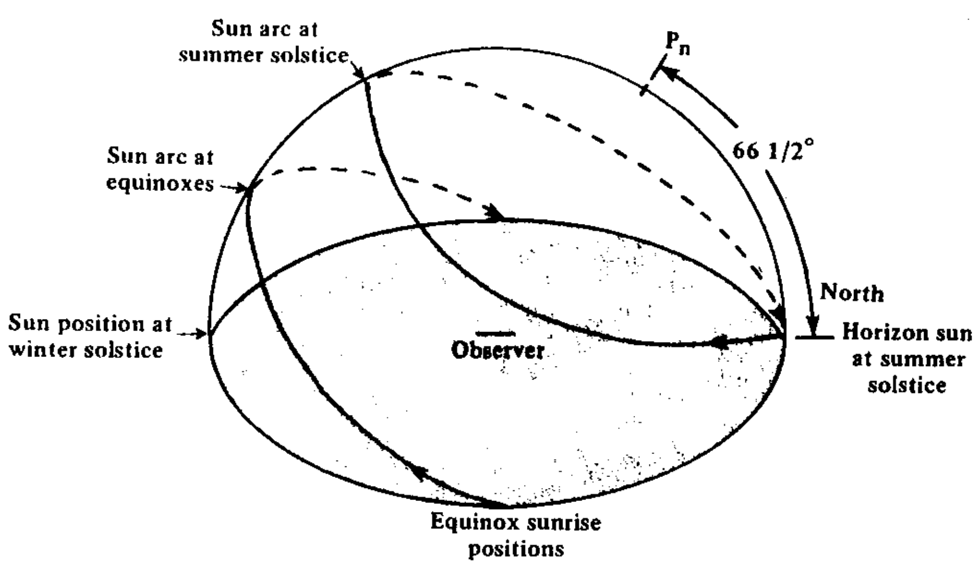


Figure 33. Sun movement from 66 1/2° north latitude.

The terrestrial latitude at which the sun remains above and below the horizon for periods of 24 hours has been designated the Arctic Circle. Between the Tropic of Cancer and the Arctic Circle the length of the longest day has increased progressively from approximately 13 1/2 hours to 24 hours. The length of the shortest day has decreased from approximately 10 1/2 hours to zero hours.

At latitude 90° N, the North Pole, the celestial equator will lie along the observer's horizon. That part of the ecliptic which is above the celestial equator will be above the horizon. That part of the ecliptic which is below the celestial equator will be below the horizon. The sun will be continuously above the horizon from the time of the vernal

At latitude 66 1/2° N, the celestial equator will cross the observer's meridian at an angle of 23 1/2° above the southern horizon. At the time of the winter solstice, the noon time sun will be 23 1/2° below the celestial equator and at the due south position on the observer's horizon. The sunrise and sunset positions will have moved 90° to the south of the due east and due west points. Since the sunrise and sunset positions coincide, the sun will not totally appear above the horizon on this day. This will be the shortest day of the year at this latitude. The sun will remain below the horizon for 24 hours.

At the time of the summer solstice, the noon time sun will be 23 1/2° above the celestial equator or 47° above the southern horizon. The sunrise and sunset positions will have moved 90° to the north of the due east and due west points. Since the sunrise and sunset positions coincide, the sun will not totally disappear below the horizon on this day. This will be the longest day of the year at this latitude. The sun will remain above the horizon for 24 hours. This latitude begins the "land of the midnight sun."

At the times of the equinoxes, the sun will rise due east, reach a maximum noontime altitude of 23 1/2° above the southern horizon, and set due west. Day and night will be of equal length. Figures 32 and 33 illustrate the motion of the sun as observed from latitude 66 1/2° N.

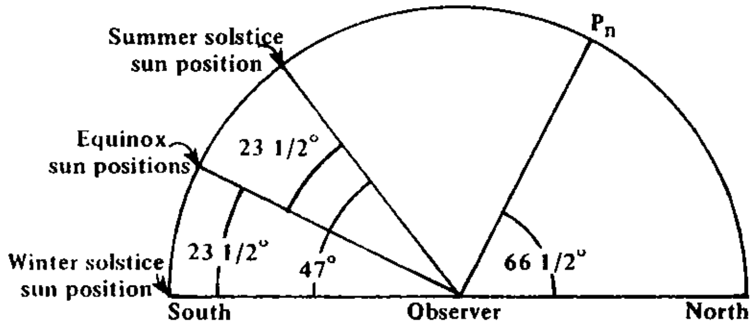


Figure 32. Sun position from 66 1/2° north latitude.

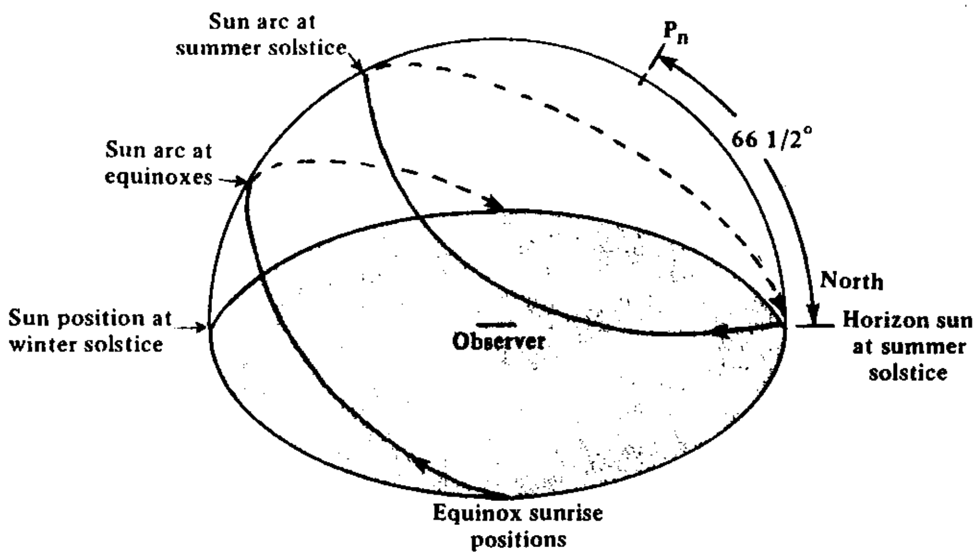


Figure 33. Sun movement from 66 1/2° north latitude.

The terrestrial latitude at which the sun remains above and below the horizon for periods of 24 hours has been designated the Arctic Circle. Between the Tropic of Cancer and the Arctic Circle the length of the longest day has increased progressively from approximately 13 1/2 hours to 24 hours. The length of the shortest day has decreased from approximately 10 1/2 hours to zero hours.

At latitude 90° N, the North Pole, the celestial equator will lie along the observer's horizon. That part of the ecliptic which is above the celestial equator will be above the horizon. That part of the ecliptic which is below the celestial equator will be below the horizon. The sun will be continuously above the horizon from the time of the vernal equinox to the time of the autumnal equinox. On the day of the vernal equinox the sun will move 360° around the horizon. The sun will repeat this motion at a slightly higher altitude each day, slowly spiraling up to a maximum altitude of 23 1/2° on the day of the summer solstice. The sun will then start to slowly spiral down toward the horizon, reaching the horizon at the time of the autumnal equinox. After being above the horizon for approximately six months, the sun will disappear below the horizon for approximately six months. Figure 34 illustrates the sun positions as observed from 90° north latitude, the North Pole.

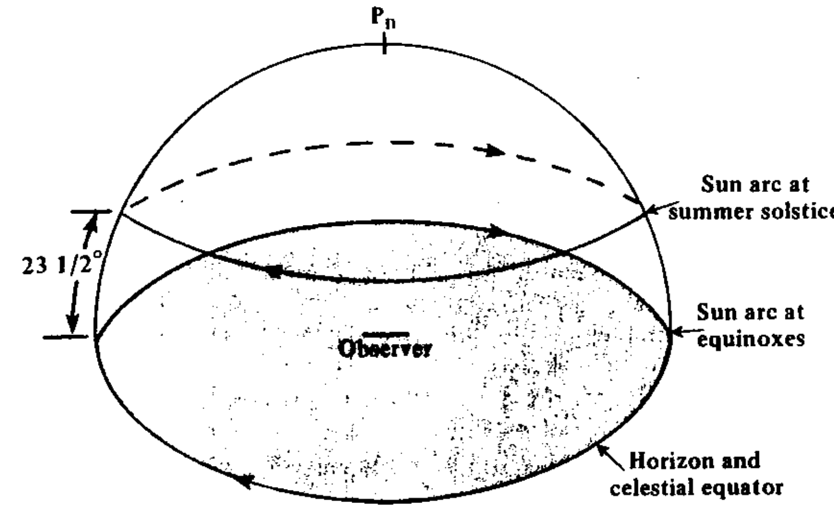


Figure 34. Sun positions from 90° north latitude.

Atmospheric refraction, which causes the sun to appear to be approximately one half a degree above its true position at the horizon, causes the "day" period to be longer than the "night" period above the Arctic Circle. The elliptical orbit of the sun, which causes the sun's apparent motion to vary, also lengthens the "day" period.

Between the Arctic Circle and the North Pole, the number of days that the sun remains above the horizon will increase from 1 day to 189 days. The number of days that the sun remains below the horizon will increase from 1 day to 176 days. Table 7 lists the length of "day" and "night" for selected latitudes within the Arctic Circle.

TABLE 7
"Day" and "Night" Within the Arctic Circle

Latitude	Length of "Day"	Length of "Night"
66 1/2°	1^d	1^d
70°	70^d	55^d
75°	107^d	93^d
80°	137^d	123^d
85°	163^d	150^d
90°	189^d	176^d

As a terrestrial observer moves from the equator (latitude 0°) to the North Pole (latitude 90°N):

1. The solstice sunrise and sunset positions will move from 23 1/2° north and south of due east and due west to 90° north and south of due east and due west at latitude 66 1/2° N.
2. The altitude of the summer solstice noon time sun will decrease from 113° above the southern horizon to 23 1/2° above the southern horizon.
3. The altitude of the winter solstice noon time sun will decrease from 66 1/2° above the southern horizon to 0° above the southern horizon at latitude 66 1/2° N.
4. The altitude of an equinox noon time sun will decrease from 90° above the southern horizon to 0° above the southern horizon.

Sun is revealed as nuke with good public relations

DAILY LOCAL NEWS, West Chester, Pa., Thurs., Nov. 10, 198?

By GEORGE REED

The sun is a nuke and potentially more dangerous than any nuclear power plant. What s more, it s in your neighborhood and there is nothing you can do about it. And in the end, it is going to get you.

The question is, "Why haven't you been warned?" The answer lies in good public relations work. You have been conditioned to love the sun, not to fear it.

Think of all the songs you have been endlessly subjected to in order to promote the sun as one of the "good guys." When John Denver sings "Sunshine On My Shoulder," do you envision ultraviolet radiation causing skin inflammations and blistering? When the Beatles musically announce "Here Comes The Sun," do you think of a huge active hydrogen bomb rising above the early morning eastern horizon? Of course not, that would be bad PR.

Let's take a look at our daytime nuke. The sun can be thought of as a celestial, thermonuclear crucible in which one element is being continuously transfo med into another element at the expense of a very small percentage of the mass involved. The result is the creation of an amount of energy every second that is so enormous, it reduced our man-made "sun" bomb into a mere finger snap.

THE THERMONUCLEAR crucible lies in the core of the sun. The temperature there is an astonishing 15 million degrees. At the tremendous temperatures and densities of the solar core, hydrogen nuclei are hurled into hydrogen nuclei. This fushion process produces helium nuclei and deadly high-energy gamma radiation. The gamma radiation appears at the expanse of mass involved.

The total mass of hydrogen nuclei involved in the fusion reaction is not equal to the mass of the created helium nuclei. What goes in does not come out in terms of mass. This difference is called the mass defect. What happens to this lost mass? It is totally and irrevocably destroyed, annihilated and obliterated. It is converted into energy.

The relationship between the mass lost and the energy gained is given by Albert Einstein's famous energy equation (E) equals mass (M) times the speed of light squared (cxc). This relationship between mass and energy was announced in his 1905 Special Theory of Relativity. The equation predicts that a very small amount of mass can produce a very large amount of energy. You could actually say a staggering amount of energy.

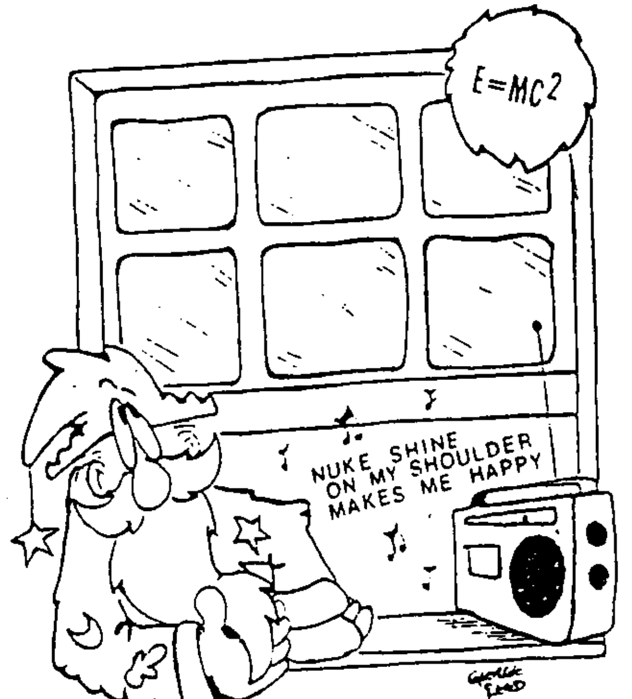
Let's be more precise. How much mass produces how much energy? The energy equivalent of a mass of one loaf of bread could provide the intake energy from food for the entire human race for one whole day. And that's just for a regular loaf. The world could get fat on a king size loaf of bread.

THE SUN converts the equivalent of the mass of four million tons of hydrogen mass into energy each second in order to maintain its normal energy output. This four million tons probably represents the mass of more bread than the entire human race has consumed since the dawn of civilization.

Before you become completely awed by the magnitude of this accomplishment, consider the reality of the nature of the sun. The sun is a lethal hydrogen fusion bomb that could easily accommodate over one million earths within its confines. The gamma radiation produced by this bomb is deadly. So what saves us?

Thank goodness the fusion reaction is limited to the core of the sun, and this core is surrounded by and confined by a hot, dense, gravity squeezed mass of gas. The gamma radiation must travel through 400,000 miles of this gas before it escapes the sun and begins its eight-minute journey to the earth. In the process it is defused to innocent sunshine, and hazardous radiation that can be handled nicely by our atmosphere.

As long as the forces of gravity can contain our solar nuke, life will be safe on earth. It will be safe at least from this particular celestial disaster.



Length of seasons affected by closeness of sun

DAILY LOCAL NEWS, West Chester, Pa., Thurs., Sept 24, 1981

By GEORGE REED

Are all the seasons of the same length? "No," you say, "because autumn began on Tuesday, and it seems like Christmas is a long way off."

But then you think, "From Christmas until the forsythia bloom at the beginning of spring always seems like an eternity." And yet, you remember that the time from the last snow of March until the end of school at the beginning of summer was always a long slow torture.

If one season is longer than the other, you may not know which one is longest, but you would probably bet that summer is the shortest season of the year. It seems to just fly right by, especially vacation weeks. Of course, if you have school-age kids, summer can seem to be about two months too long.

The truth is that the seasons are of different lengths. We have just passed through the two longest seasons of the year, and we are now entering our two shortest seasons of the year.

Spring began March 20 this year and ended June 21. We had a 93-day spring. Summer began June 21 and ended Tuesday. We also had a 93-day summer.

Autumn will end Dec. 21 after lasting only 90 days. Winter will begin Dec. 21 and end March 20, only 89 days later.

You may guess that the combined spring and summer seasons are seven days longer than the combined autumn and winter seasons because things expand when they are heated and contract when they are cooled. You would be wrong in guessing this. The seasons are of different lengths because of the earth's orbit and motion around the sun.

The earth revolves around the sun in an elliptical orbit. An ellipse is an oval curve having two points on its longest axis of symmetry such that the sum of the distances from each point to any place on the curve is constant. (Non-mathematicians think of ellipses as squashed circles.) The sun is at one of these points; the other point is empty.

The position of the earth at the end of each season is 90 degrees away from where it was at the beginning of each season. The seasons have different lengths because the earth does not travel through these 90-degree segments at the same speed.

When the earth is closest to the sun, at the perihelion point of its orbit, it travels its fastest. It revolves then at a speed that is a little faster than its 18.6 miles per second average speed around the sun. The earth reaches the perihelion point of its orbit during the first few days of January.

It is therefore moving fastest at the end of the autumn season and beginning of the winter season.

Moves slower

When the earth is farthest from the sun at the aphelion point of its orbit, it travels its slowest. It revolves at a speed that is a little slower than its 18 6 mile per second average speed. The earth reaches the aphelion point of its orbit during the first few days of July. It is therefore moving slowest at the end of the spring season and beginning of the summer season.

The combined spring and summer seasons are seven days longer than the combined autumn and winter seasons, because in the spring and summer, the earth is farthest from the sun and moving its slowest.

This is not what you would expect as far as the seasons are concerned. It would seem that the earth should be closer to the sun in the spring and summer. The paradox is explained by another factor that has a more important effect on the weather than the three percent change in our distance from the sun during the year.

Our seasons are determined by the length of time the sun is above the horizon and how high it gets during the day. Long days heat the earth; short days cool the earth.

Why are the days longer in the summer and shorter in winter? Would you believe because things expand when they are heated and contract when they are cooled?