

Earth, Sun, and Seasons



WHAT IS ASTRONOMY?

Astronomy (Greek: literally, "*law of the stars*") is the science of celestial objects and phenomena that originate outside the Earth's atmosphere, such as stars, planets, comets, aurora, and galaxies. It is concerned with the formation and development of the universe, the evolution and physical and chemical properties of celestial objects and the calculation of their motions. Astronomical observations are not only relevant for astronomy as such, but provide important information for the proving fundamental theories in physics, such as Einstein's general relativity theory. Most of what we know about the universe we learn by observing the light or electromagnetic radiation that reaches earth.

Astronomy is one of the oldest sciences, with observations on record dating back thousands of years. Historically, amateurs have contributed to many important astronomical discoveries, and astronomy is one of the few sciences where amateurs can still play an active role.

Modern astronomy as practiced is not to be confused with astrology, the belief system that states that people's destiny and human affairs in general are correlated to the positions of celestial objects in the skies. Although the two fields share a common origin, they are quite different; astronomers employ the scientific method, while astrologers do not.

Astrophysics is the branch of astronomy that deals with the physics of the universe, including the physical properties (luminosity, density, temperature and chemical composition) of the stars, galaxies, and the interstellar medium, as well as their interactions. The study of cosmology is theoretical astrophysics at the largest scales. Modern astronomical research involves a substantial amount of physics.

Astronomy also utilizes some of the most advanced technology. It has consistently provided evidence into where we came from as well as how matter and energy are related to each other.

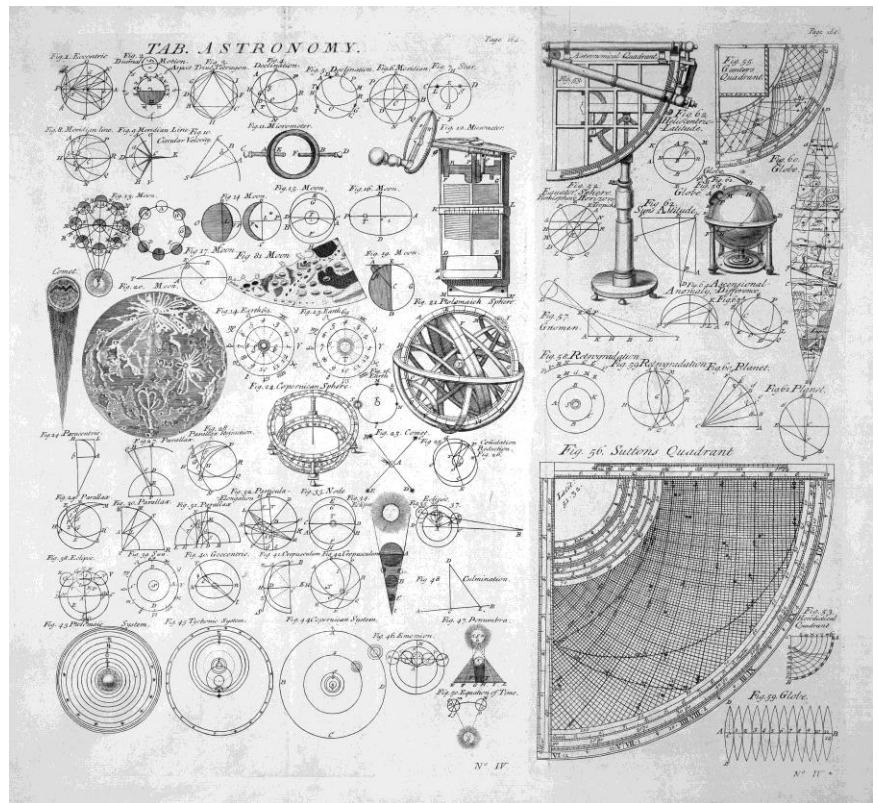


Figure 1.1 Table of astronomy, from the 1728 Cyclopaedia



DESCRIBING THE LOCATION OF CELESTIAL OBJECTS

In order to study the motion of celestial bodies, collect data, and describe their motions, it is important that we come up with a way to consistently determine their location or position in the sky. You should be familiar with determining and describing direction using a compass rose – NORTH, SOUTH EAST AND WEST. You should also know that there are 360 degrees in a circle.

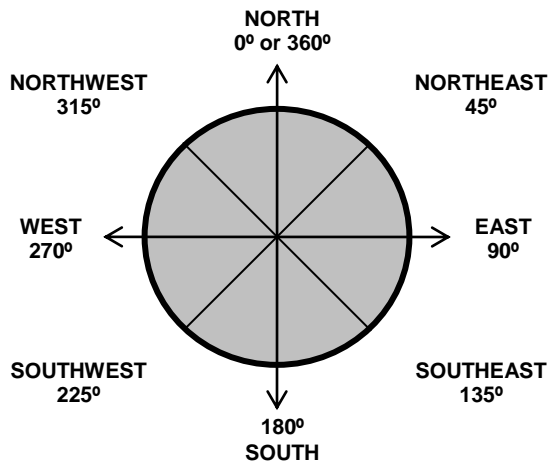


Figure 1.2 Direction along with azimuth

In astronomy, we use the term **azimuth** to describe direction. **Azimuth** is the horizontal component of a direction (**compass** direction), measured around the **horizon** usually from North in a clockwise direction and is usually measured in **degrees**.

The distance of a star from the horizon is called it's **altitude**. In the example below, the altitude of the sun is 60 degrees above the horizon. Simply reporting the altitude does not tell you which direction to look to see the object however. To report or record the altitude *and* azimuth will give the precise location in the sky. In terms of a coordinate system, think of azimuth as the x-axis and altitude as the y-axis. So, in the example below, the sun is located at (135,60) following the familiar (x,y) convention.

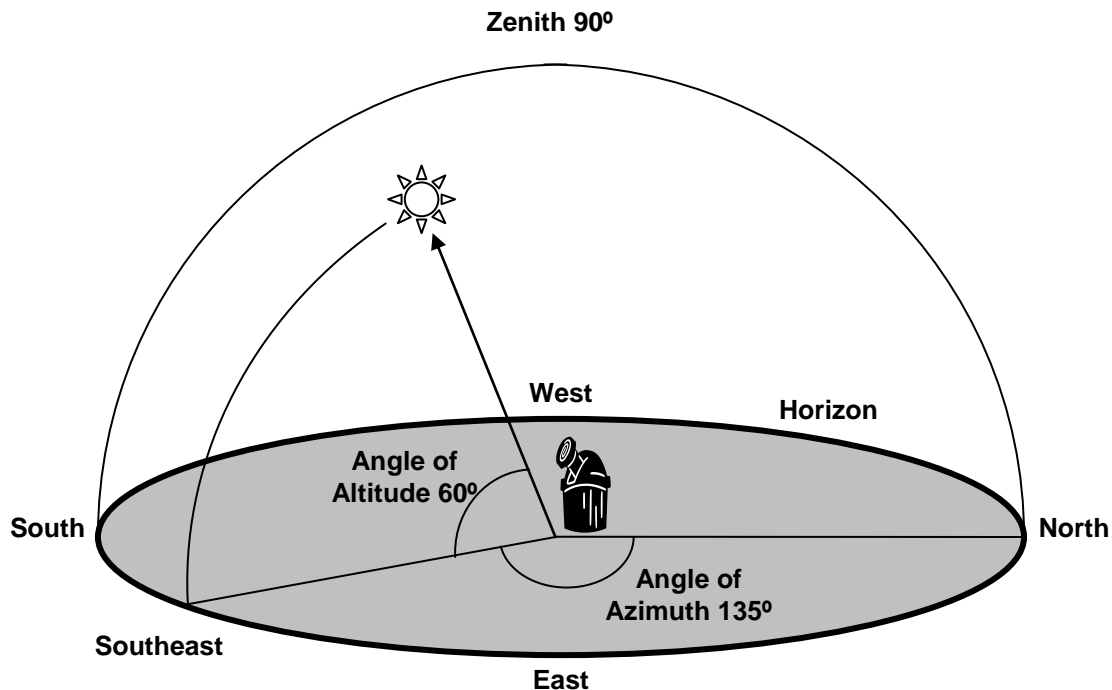


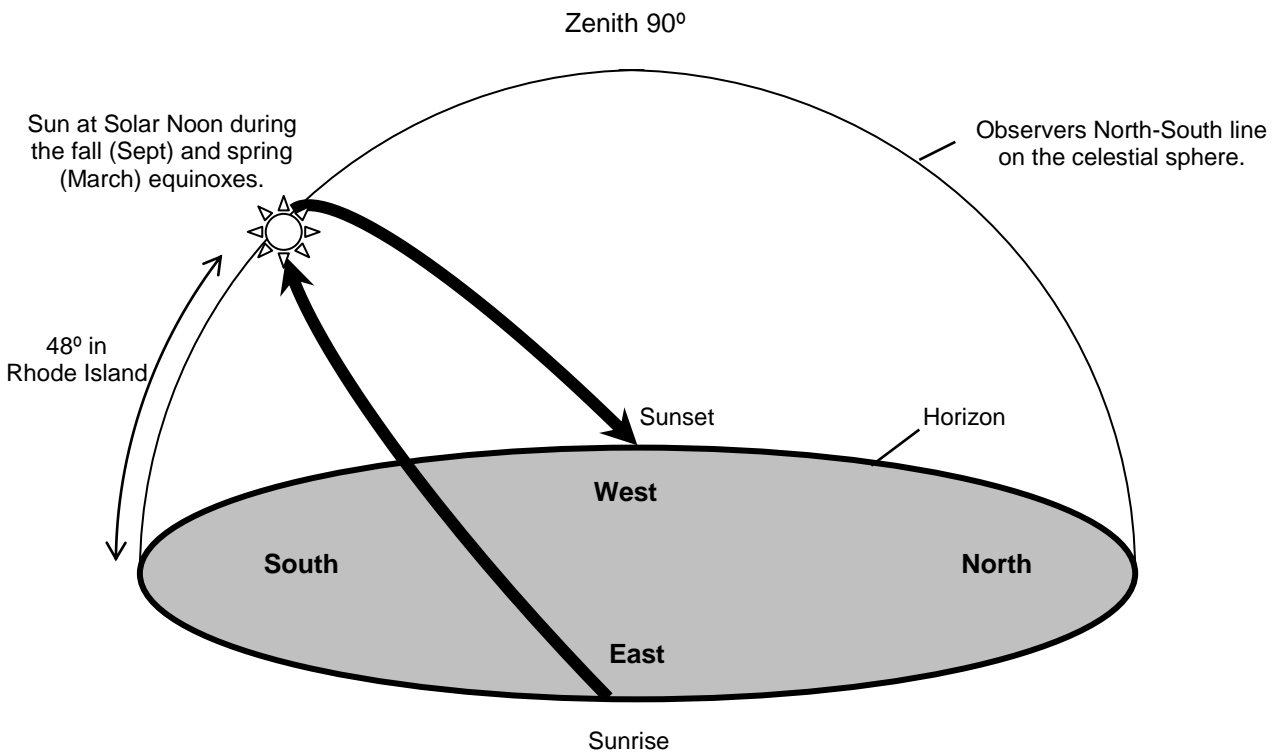
Figure 1.3 The location of the sun is (135,60) following (x,y) convention.



THE SUN'S APPARENT MOTION

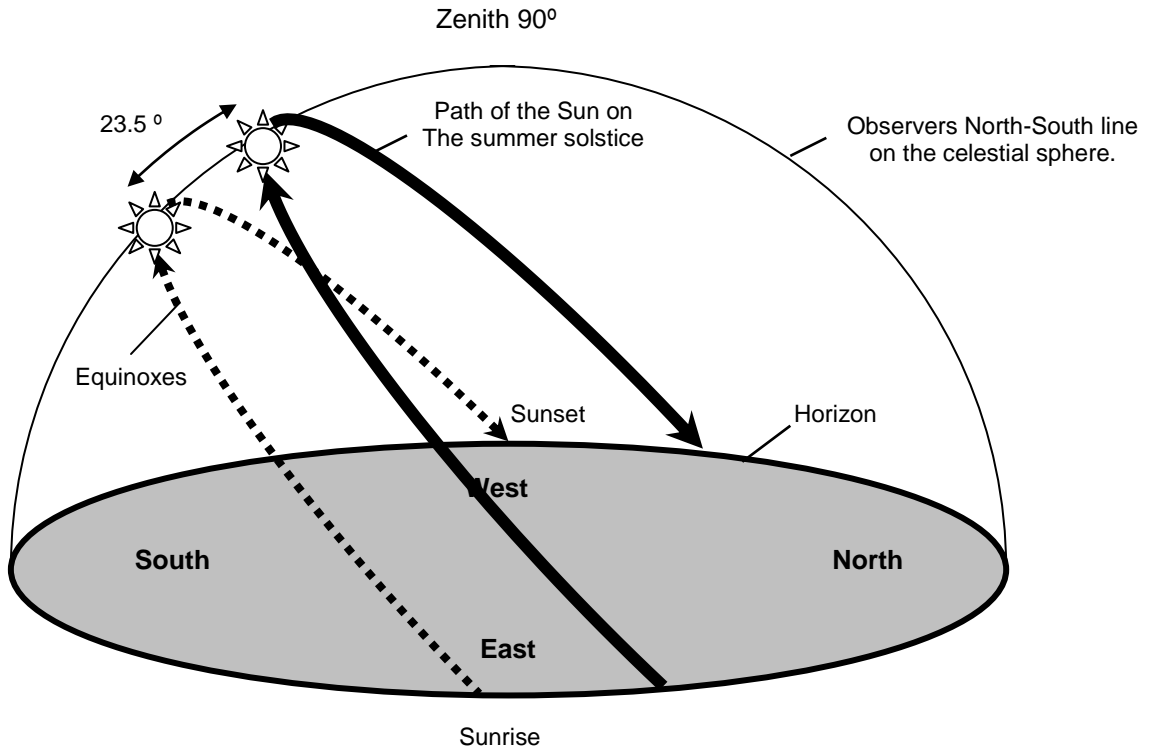
In order to better understand our place in the universe, it would make sense to start by looking at objects that are familiar to us. Most Rhode Islander's understand that the sun generally rises in the East, moves across the southern sky and sets in the West. The following diagram attempts to illustrate the apparent motion of the sun from sunrise to sunset. In this case, the sun rises due East and sets due West on the fall and spring equinoxes. It "moves" across the southern sky reaching a maximum altitude at solar noon of about 48 degrees here in Rhode Island. We use the term solar noon to describe when the sun crosses the 180 degree azimuth position. During both the vernal and autumnal equinoxes, there are equal hours day and night – roughly 12 hours of daylight and 12 hours of darkness.

In reality, we know that the earth is the one that is doing the moving. It takes Earth approximately 1 day to rotate once on it's axis. I use the word approximately because there is more that needs to be explained about what makes up a day, and how we determine how long a "day" is.

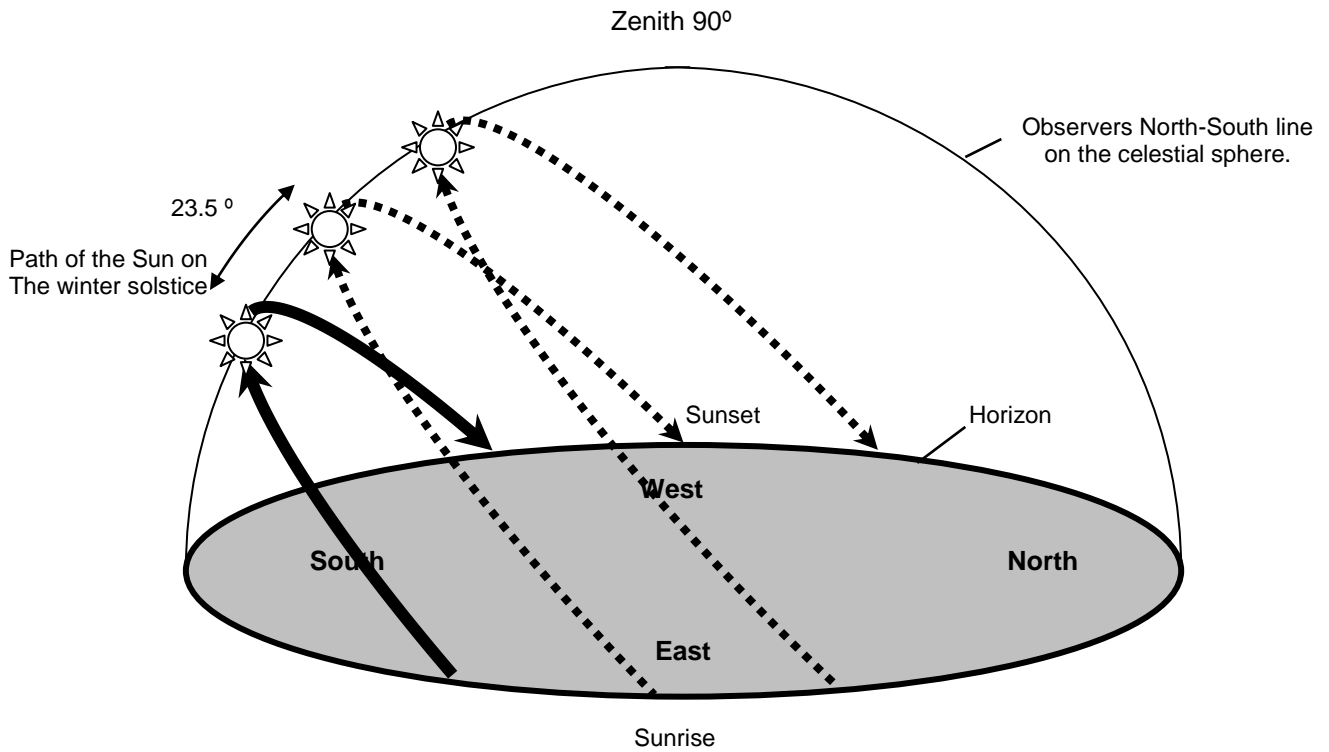


If you were to observe the sun rise and set over the course of one year, you would find that it changes it's rise and set position, as well as the altitude at solar noon. The two diagrams on the next page illustrate this observation. If in the above situation, it were the vernal or spring equinox, you would progress into summer watching the sun rise and set north of east. The days would get longer, and the sun would streak across the sky higher and higher at solar noon until on or about June 21st, also known as the summer solstice. On this day, the longest day of the year, there are roughly 15 hours of daylight and 9 hours of darkness. The sun crosses the meridian at an altitude of about 71.5 degrees, roughly 23.5 degrees *higher* than it was on the equinox.

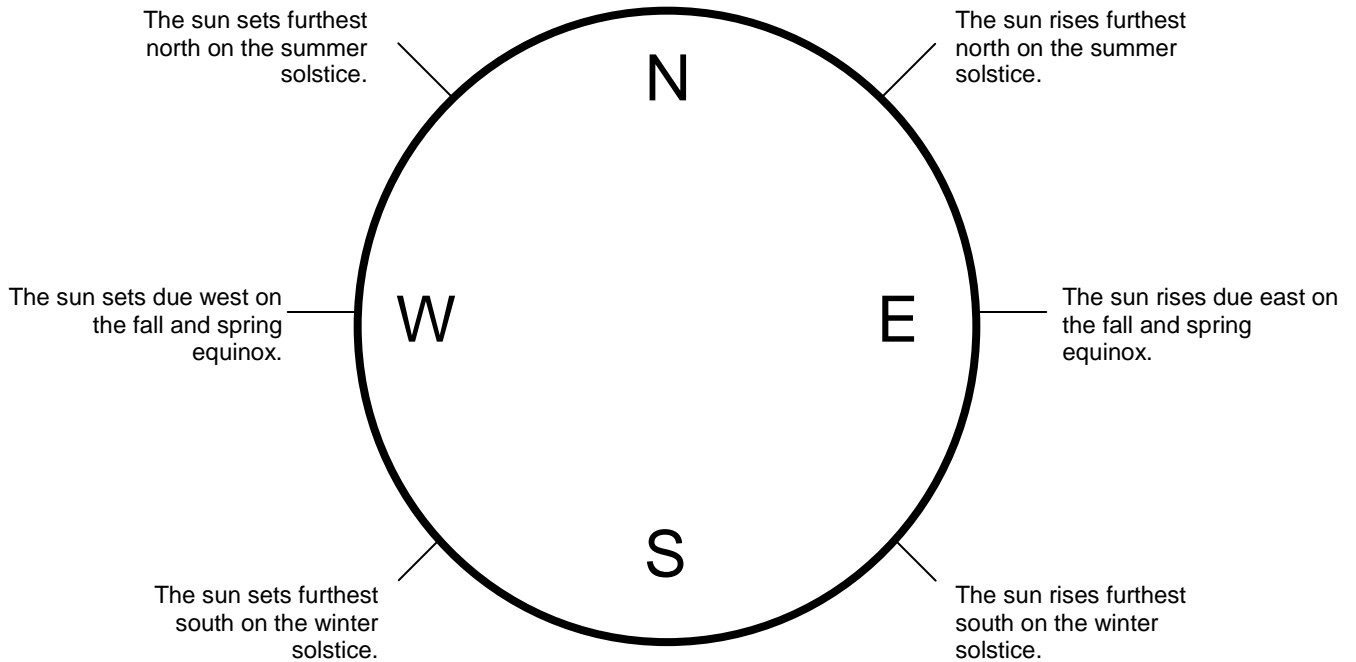
Conversely, during the winter solstice, the sun rises and sets furthest south of east. On this day, the shortest day of the year – with roughly 9 hours of daylight and 15 hours of darkness, the sun reaches a maximum altitude at solar noon of only roughly 24.5 degrees here in Rhode Island.



Apparent path of the sun on the summer solstice – June 21st.



This next illustration, is from the zenith (directly overhead) looking down on the observer at the center of the circle. The outer edge of the circle represents the horizon, with the observer at the center of the circle.

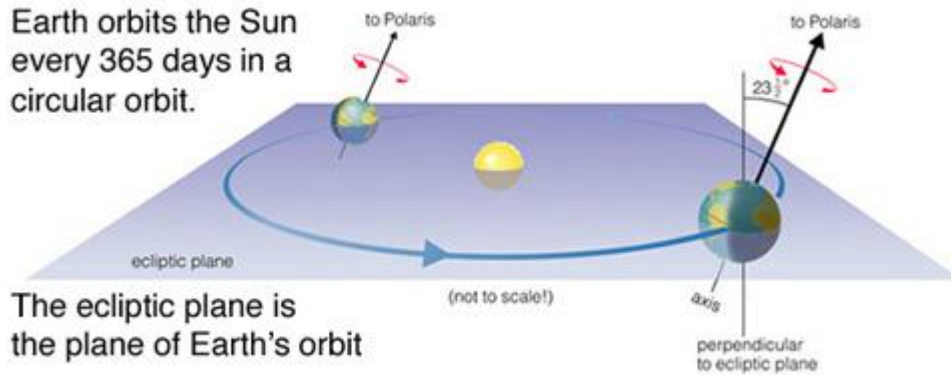


The apparent rising and setting of the sun is predictable. I like to use these diagrams to demonstrate the pattern of rise and set azimuth, that is difficult to understand with other models. What you might be able to tell from the diagram, even without actual data, is that the sun appears to rise the same number of degrees *north* of east that it sets *north* of west on the summer solstice. It rises due east and sets due west on the equinoxes, and then rises the same number of degrees *south* of east that it sets *south* of west on the winter solstice

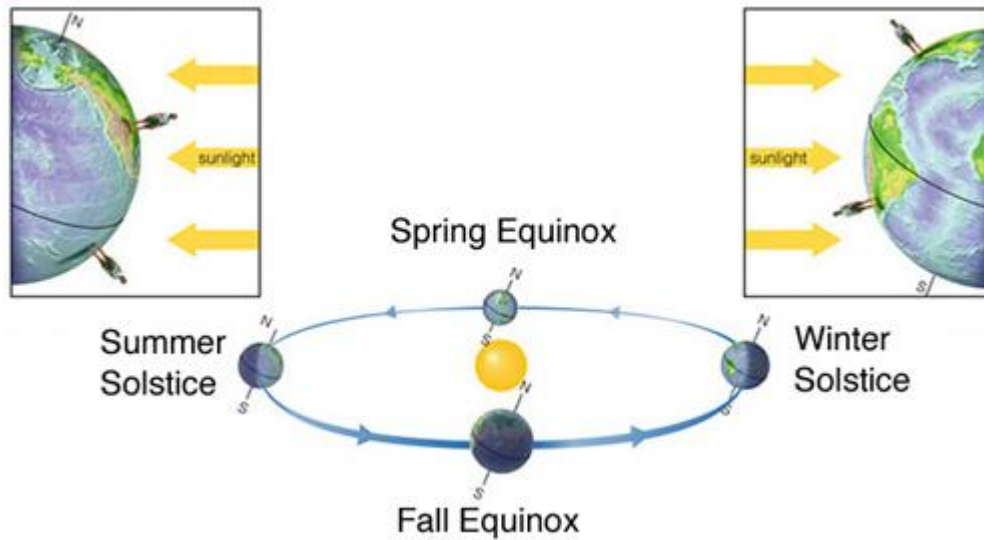
<p>A circular diagram with 'N', 'S', 'E', 'W' labels. A curved arrow on the left side indicates the sun's path from the top-left (labeled 'JUN') to the bottom-left (labeled 'DEC'). The path passes through 'JUL', 'AUG', 'SEPT', 'OCT', and 'NOV'.</p>	<p>A circular diagram with 'N', 'S', 'E', 'W' labels. A curved arrow on the left side indicates the sun's path from the bottom-left (labeled 'DEC') to the top-left (labeled 'JUN'). The path passes through 'JAN', 'FEB', 'MAR', 'APR', and 'MAY'.</p>
<p>Changing rise and set azimuth between June 21st (summer solstice) and December 22nd (winter solstice).</p>	<p>Changing rise and set azimuth between December 22nd (winter solstice) and June 21st (summer solstice).</p>

'Tis the Seasons

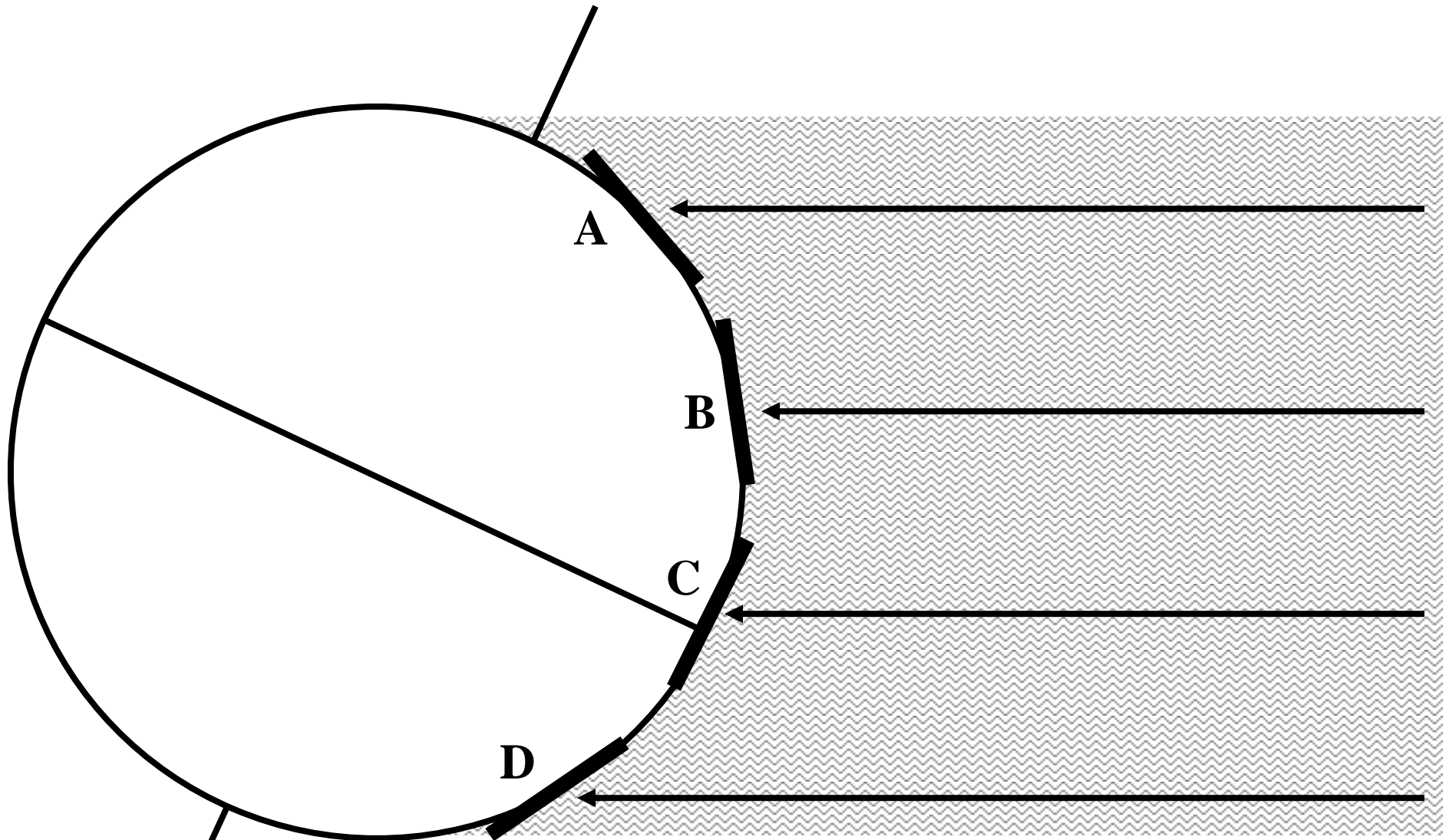
Seasons on Earth are mainly caused by the 23-degree tilt of its spin axis. This axis points in a fixed direction toward Polaris (also known as the North Star or Pole Star). The diagram shows an oblique view of Earth's roughly circular orbit.



Because Earth's axis tilts with respect to its orbital plane, the angle of the sunlight we receive in different places over the globe changes during the year. From March until September, when the North Pole points toward the Sun, the days are longer, the Sun is higher in the Northern Hemisphere, and we have northern summer and southern winter. Because Earth's orbit is very close to circular, the slight change in distance between the Earth and the Sun does not cause any appreciable change in sunlight. In fact, we are slightly closer to the Sun in December than we are in July.



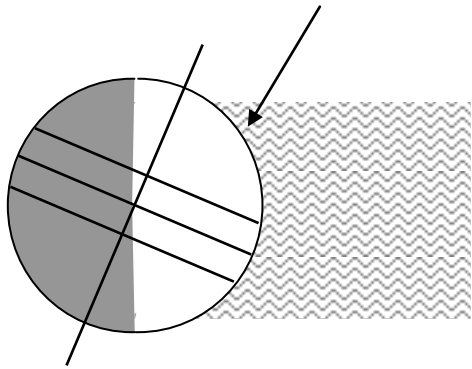
This diagram refers to seasons experienced in the Northern Hemisphere. The Southern Hemisphere has equinox (equal night and day) at the same time, but experiences winter while it's summer in the north and vice versa.



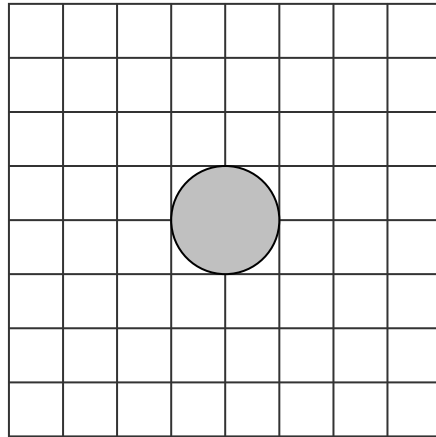
In this diagram, points A, B and C would be experiencing summer, while point D would be experiencing winter. Point B observes the sun's rays most directly overhead, followed by point C, then point A and point D closely behind. You can measure the angle by placing a protractor parallel with the surface of the Earth at each point.

SUMMER IN RHODE ISLAND

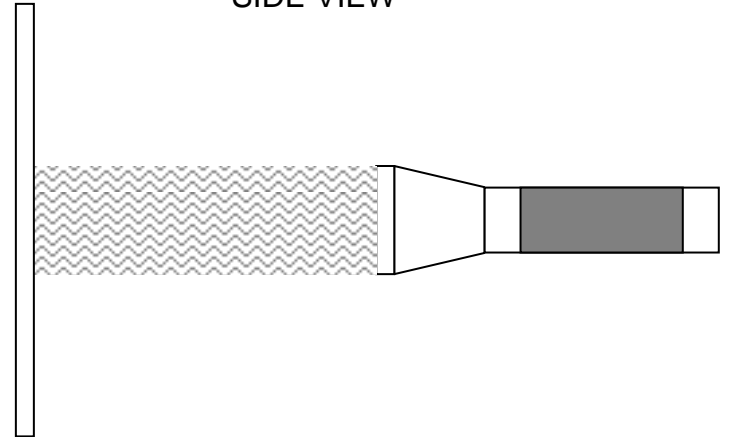
SUMMER IN RHODE ISLAND



VIEW FROM LIGHT SOURCE

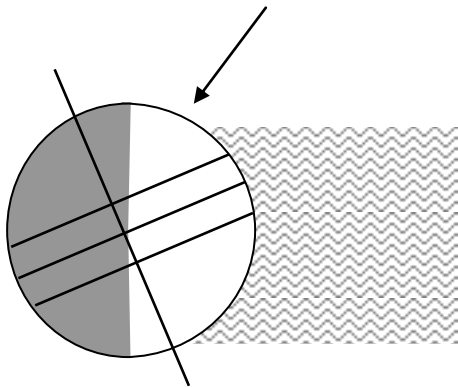


SIDE VIEW

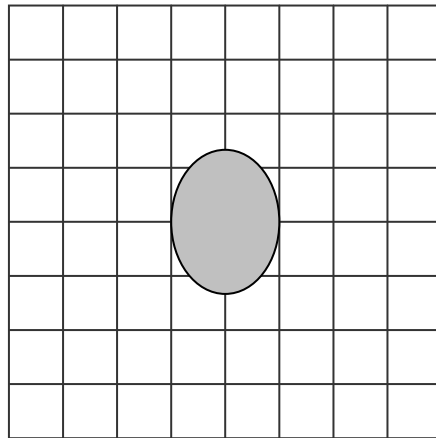


WINTER IN RHODE ISLAND

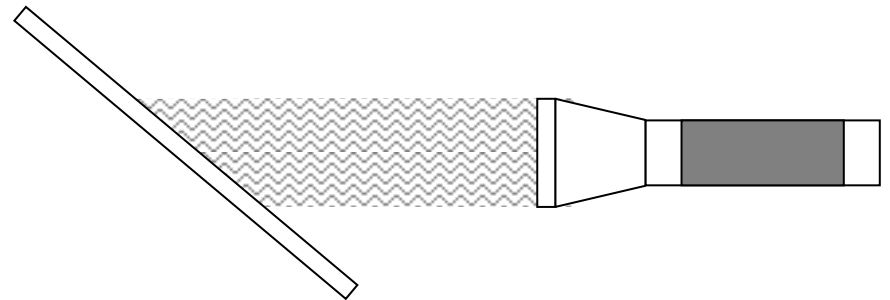
WINTER IN RHODE ISLAND



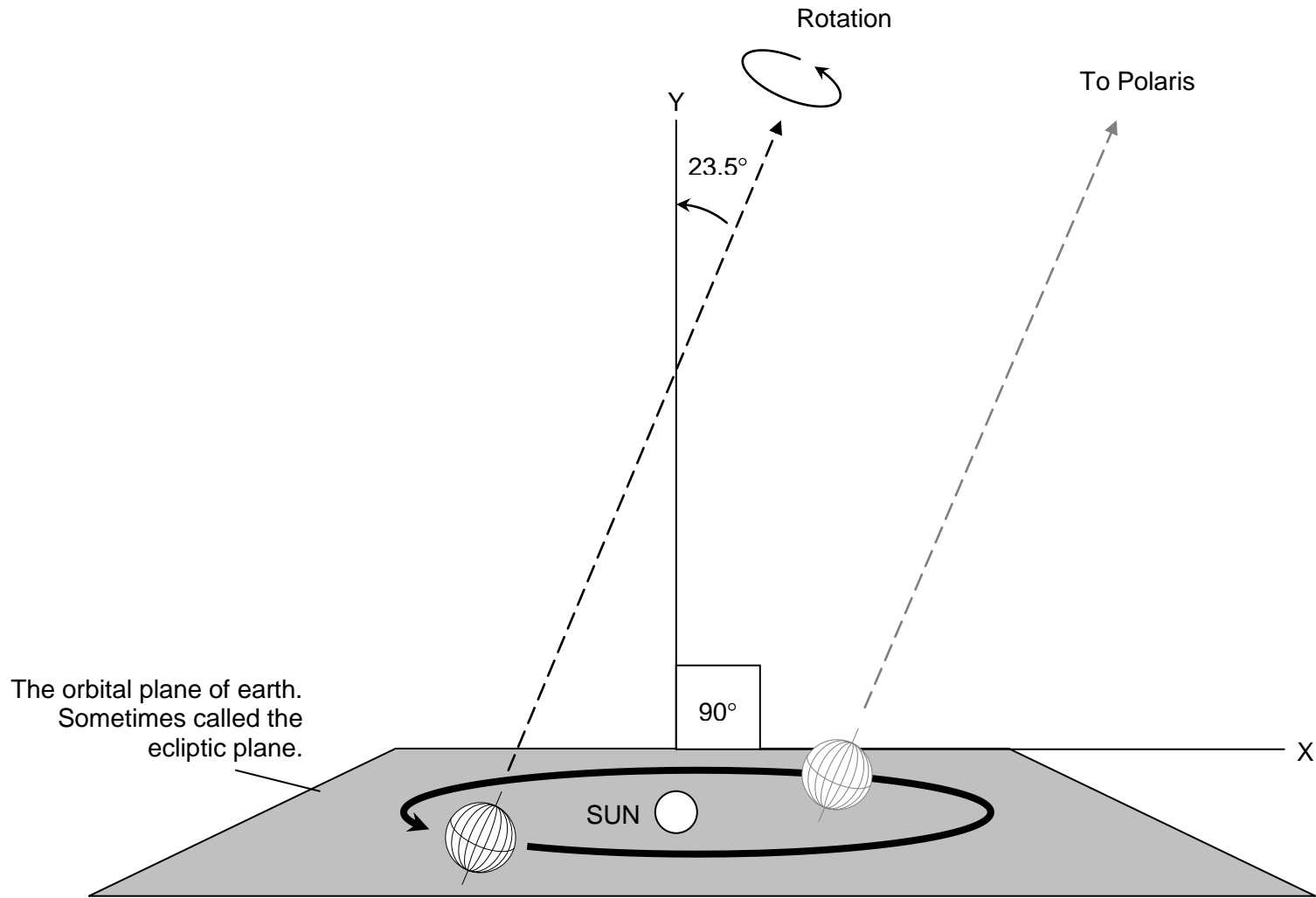
VIEW FROM LIGHT SOURCE



SIDE VIEW



This diagram demonstrates how the angle of the sun changes the concentration of light that affects a given area. In each instance, the same amount of light is being emitted from the light source. However, when the light strikes the “flat” plate at a steep angle (90 degrees), the light is much more concentrated. When the light strikes the “tilted” plate (~45 degrees) the same amount of light covers a larger area, and therefore is less concentrated on one area. The result is that the light source has less of a heating effect at lower angles than it does when it is directly overhead.



This diagram attempts to show you the angle that the earth is tilted relative to it's orbital plane. It maintains this 23.5 degree tilt while rotating once every 24 hours on it's axis and completing one revolution around the sun in approximately 365 days. The view is from the side and slightly elevated.

