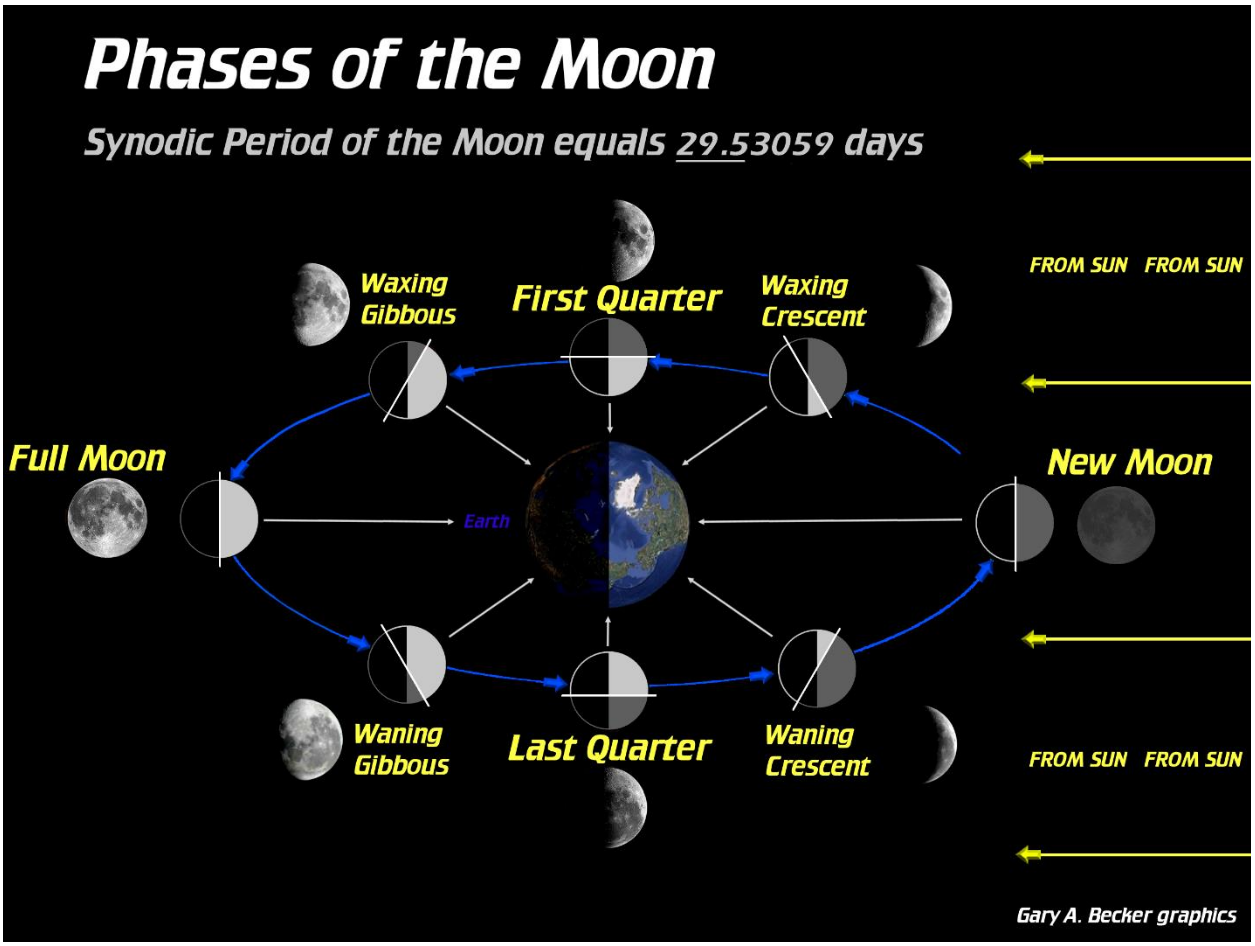
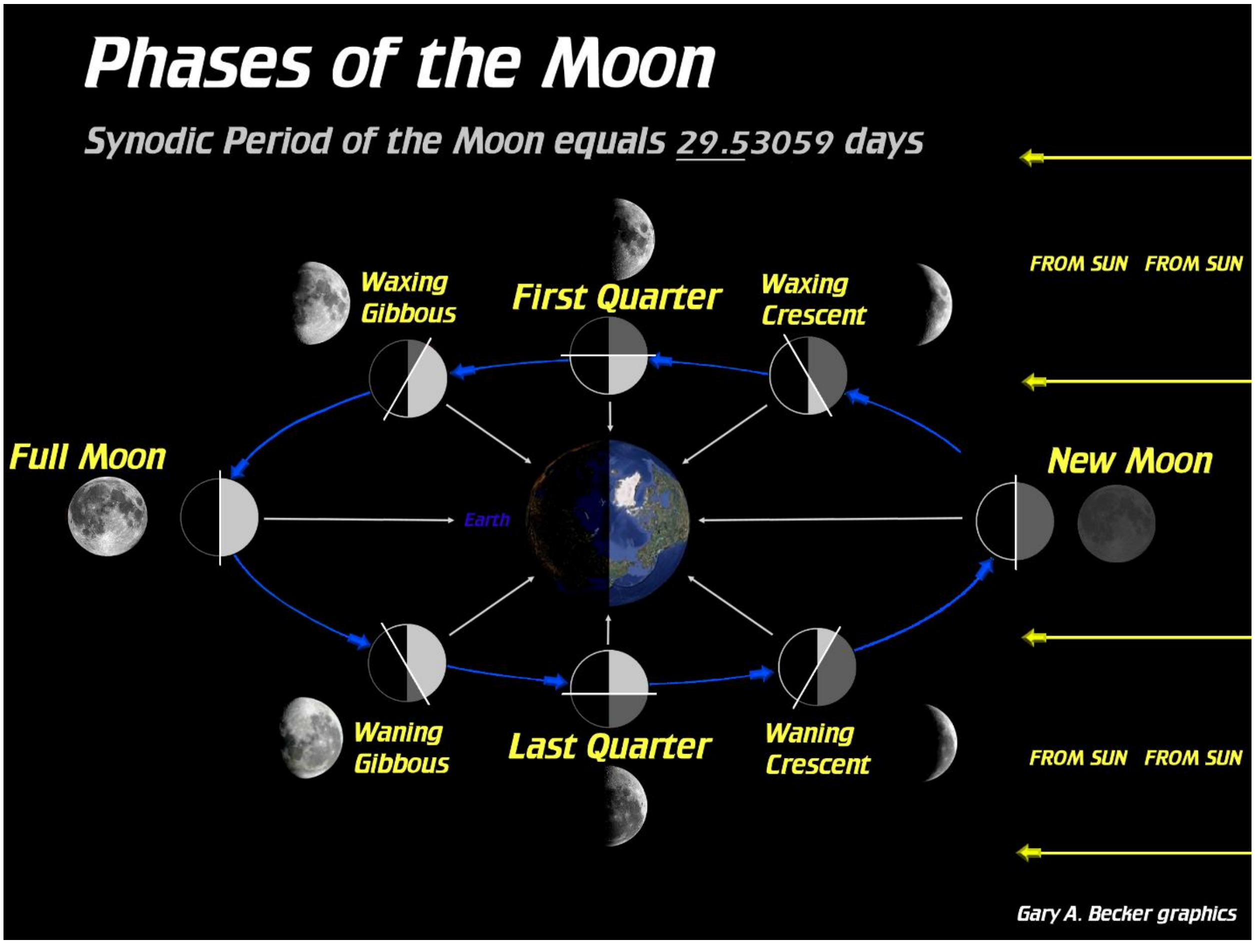
Misconceptions Regarding the Moon
Reasons for the Seasons

This lesson transcript has gone through two edits. The content is good, but there may be some grammatical errors.

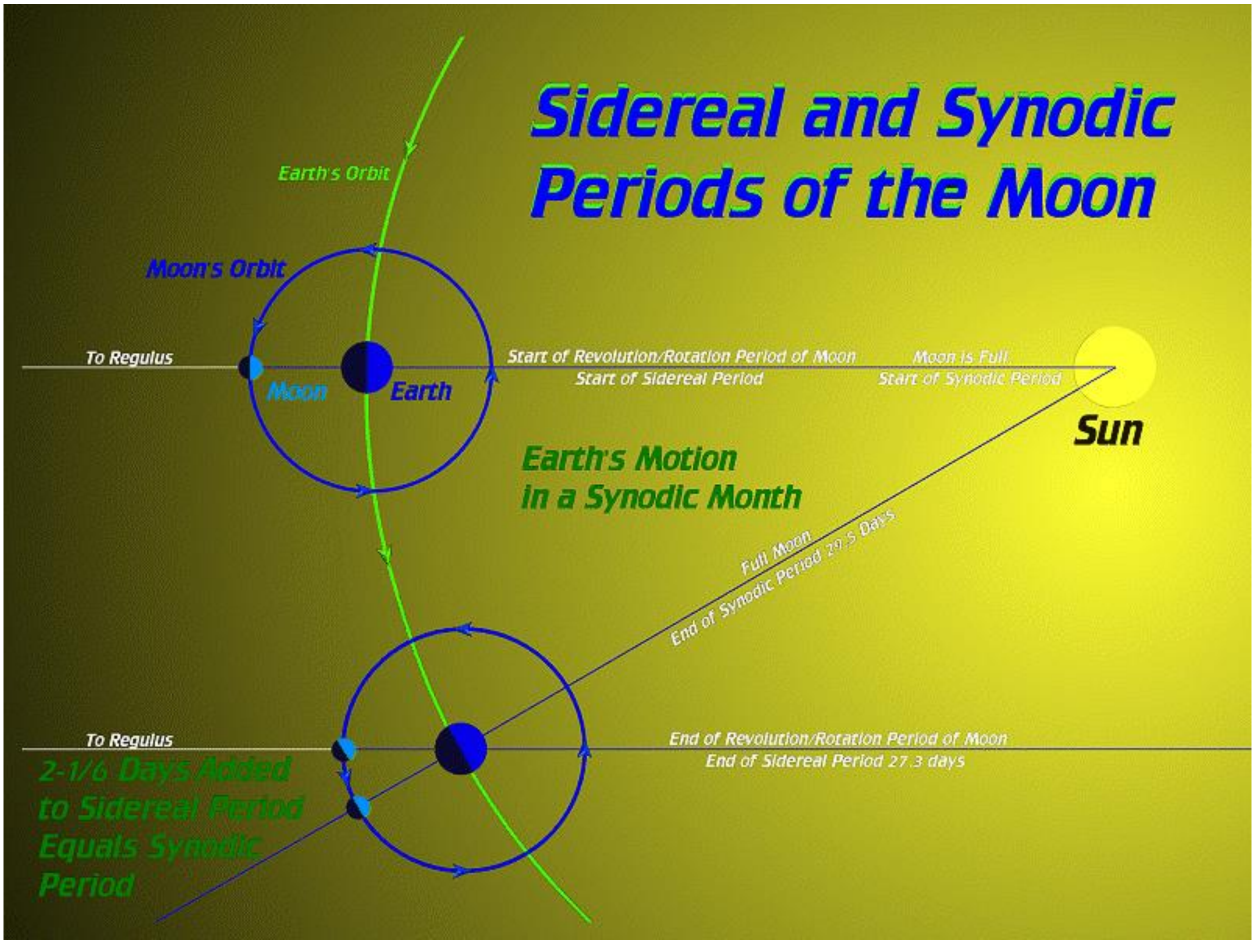


We have the moon orbiting around the Earth in this slide. You can see that at any one particular moment, only half of the moon is being illuminated by the sun. This is represented by the half of the moon positioned towards the sun which contains the light and dark greys. The very light grey represents the part of the moon that is in sunlight creating the phase that we would see if we were outside observing the moon. The darker grey is that portion of the sunlit moon which is on the moon's far side which is invisible to an observer's eyes from the Earth.

This is the way the moon's phases might be represented in a textbook. Remember that as we observe the moon going through its phases, we are actually witnessing the moon going through a day and night sequence. The part of the moon that is perpendicular to the line of sight of the observer is the portion of the moon visible to that individual. It is creating the particular phase of the moon that I that can be seen in the sky. The first quarter is simple, because you can see that the right half of the moon is lit and the left side is still in its own shadow. Here is the waxing gibbous phase with more than half of the moon in sunlight. With the full moon, we can see that the far side of the Moon is in night and the near side is completely in sunlight. The far side goes through a day and night sequence just like the nearside. There is no dark side of the moon. As the moon continues to revolve around the Earth, the phases reverse themselves. The moon is now waning, beginning with a waning gibbous, third quarter, and finally a waning crescent. I need to say one thing about the first quarter moon and the last quarter moon because it looks as if the wrong side is illuminated on the third quarter moon. This is not the case. I have to look at the moon in an upside-down position which means my left and right will be reversed. I would have to hang my head, and someone would have to hoist me up upside down if I wanted to observe the moon correctly. Because I'm standing on the Earth in an upside-down position, my left and right would be switched and the light of the third quarter moon would appear on the left as it should be seen.



What I'm going to do is put my index finger on the lit portion of the first quarter moon; my thumb will be placed on the nighttime portion of the same phase moon. The reader can do this with the above image. Keep in mind that the moon keeps its same face pointed towards the Earth. As I come around to the third (last) quarter moon, my index finger is now on the portion of the third quarter moon that is in darkness. It is in the opposite hemisphere of the last quarter moon and it is now in darkness. If I back up around to the first quarter moon, my index finger is in sunlight once again.

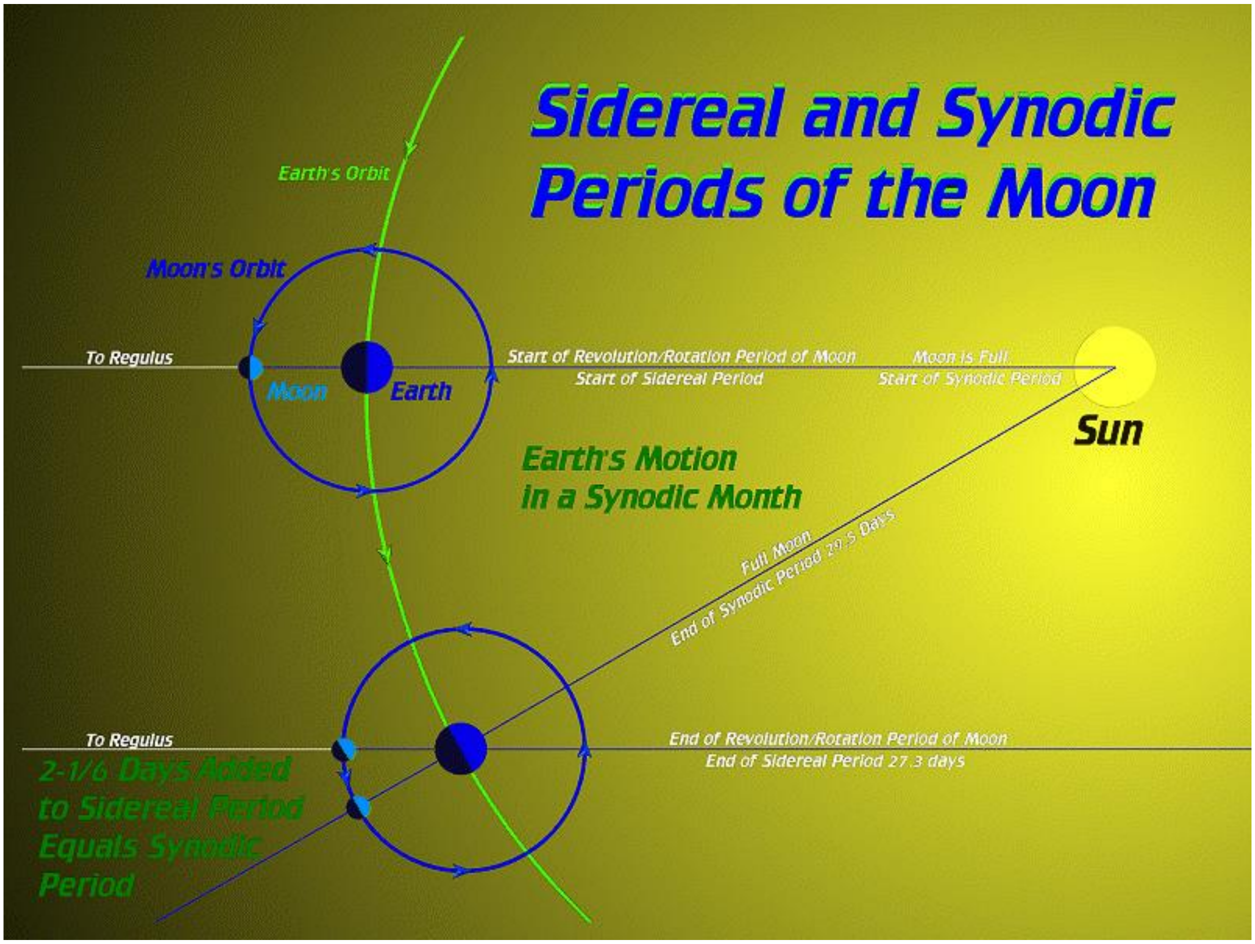


I also need to say something about the two major periods of the moon, the sidereal and the synodic periods. When we talk about eclipses, we will get into this in a little more detail. This is a rather difficult concept that students have some issues in understanding. If I teach it twice, once here and once with eclipses, there will be a little more comprehension. When we talk about eclipses, I will be teaching four different periods that the moon goes through. The two that get the most traction in astronomy texts are the sidereal and the synodic periods. I want to preface that you have all heard of these intervals before, but you have probably not heard of the astronomical word that is associated with them. The revolution of the moon around the Earth is called the moon’s sidereal period. We have just given it a different name. We have certainly talked about the phases of the moon, and that is equal to the synodic period.

Here is what a lot of people don't realize. The synodic (phase) period of the moon is not the same as the time it takes the moon to complete one orbit around the Earth, the lunar sidereal period. The synodic period is 29.5 days and the sidereal period is 27.3 days.

If you're an elementary teacher, and you have to teach these concepts to third or fourth graders, you might just say it is too much for the kids to grasp at that young age. I would agree with the teacher. The instructors might say, if I take the sum of 29.5 and 27.3, and divide by two, I will get a number close to 28 (28.4). So, it takes 28 days for the moon to go through all of its phases, and it takes 28 days for the moon to make one revolution around the Earth. Now that teacher has taught two concepts incorrectly to the class. Those poor third graders are like sponges, soaking in that misconception until they grow up and are in my class. Now I have to deal with the problem.

I used to say to our third-grade teachers in Allentown, forget about the revolution of the moon around the Earth. No one is interested in that. People are interested in the phases of the moon. That's what you see as you watch the moon going through its day and night cycle. Rather than get concepts confused, just hype, the 29.5-day synodic period. That is the one that we can easily observe and it is also the concept that needs understanding when eclipses are discussed.



Because this is a college class, I would like you to understand these particular lunar periods. I constructed this slide (above) to help everyone understand these two intervals, the synodic and sidereal periods of the moon. We have the sun over on the right of the slide. A straight line from the sun through the middle of the Earth through the middle of the moon, and outward to the star Regulus in the constellation of Leo the Lion is the starting position for the synodic and the sidereal periods. Regulus is very close to the ecliptic as is the moon. The Earth and sun are on the ecliptic, so the drawing is an accurate representation of the configuration.

The word sidereal comes from the Latin. It means the star period. When this is all mentally set into motion, I'm going to watch the moon with respect to its passing of Regulus. When observers on the Earth see Luna passing Regulus for a second time, it will have completed one orbit around the Earth. Note that the moon in the upper drawing is in the full phase. As everything goes into mental motion, the moon's orbital period (sidereal) and the phase period (synodic) start at the same moment. Which period will finish first and which will finish second?

Put yourself on the earth looking at the moon. Does everybody see that the moon starts off in a full phase?   I say go and everything starts moving in my mind.   This is not a static concept. The moon is revolving around the Earth, and when the moon comes around to the same orientation with Regulus that it was in the first picture—sun, Earth, moon, and Regulus, the sidereal (orbital) period will have been completed. A total of 27.3 days will have transpired.   But look at the phase of the moon, putting yourself on the Earth again. Is the moon full? Yes or no? The answer is no. The phase is a waxing gibbous.

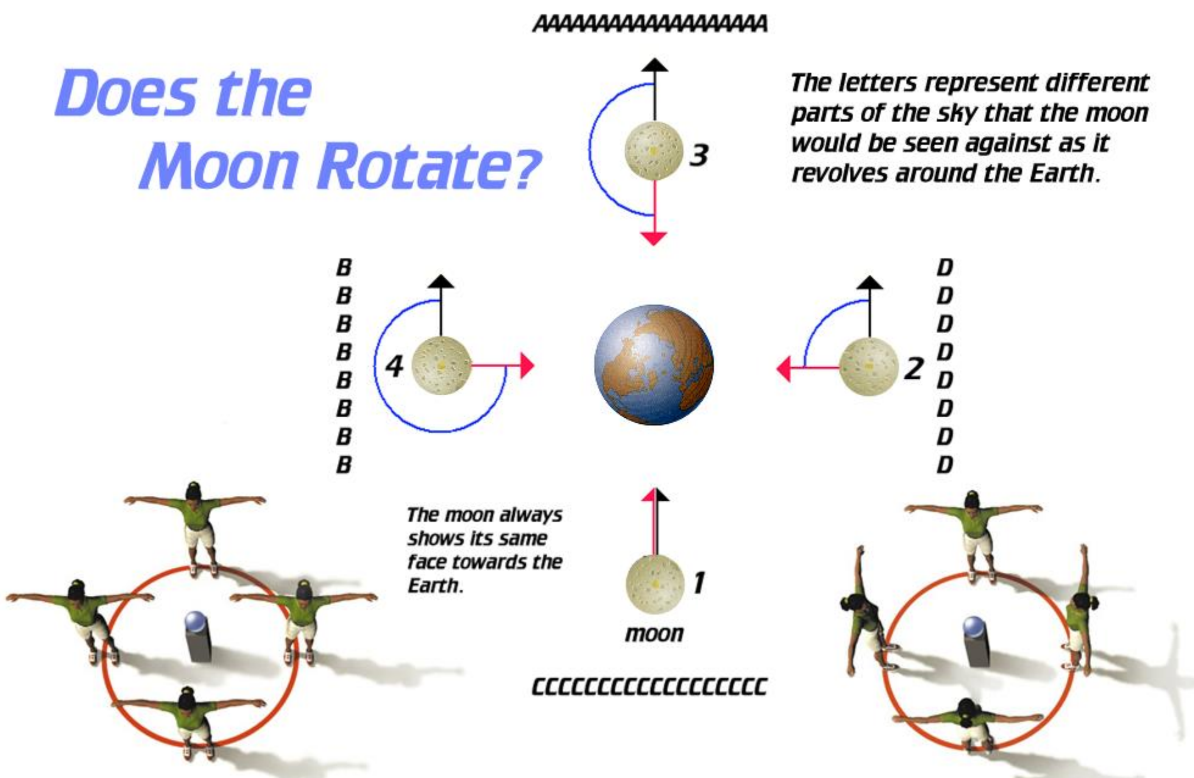
The sidereal period has ended. What does the moon need to accomplish if it wants to get back to a full phase and complete the synodic period? I'm personifying the moon here. The moon is going to continue moving in its orbit around the Earth. Eventually, it will be in a situation where the moon, the Earth, and the sun, will again be in a straight line and the full moon phase will be repeated. The phase period has come to an end.

The question becomes, how long does it take the moon to go through this small angle, the angle that will allow it to catch up to the full moon phase? What amount of time must I add to the sidereal period to equal the synodic period? It turns out that the average amount of time that I have to add to the sidereal period is about 2-1/6 days. Adding 2-1/6 days to 27.3 (27-2/6) days equals the synodic period of 29-3/6 days or 29.5 days.

We are going to pretend that the synodic period is a fixed amount of time. For us it will always be 29.5 days, actually, 29.53 days. In reality the synodic period does vary from about 29.4 days to about 29.6 days depending upon whether the Earth is closer (perihelion) or farther (aphelion) from the sun. When the Earth is at perihelion closest to the sun in the winter (January 2 or 3), the Earth is moving fastest in its orbit. Therefore, the Earth will move through a larger angle before the sidereal period is completed. The moon will have to also move through a larger angle to catch up to the correct phase period, a full moon, and thus complete the synodic period. I'll be delighted if you remember 29.5 days as the average of one phase cycle. I definitely need you to understand why the orbital period of the moon (sidereal) is different from the phase (synodic period) of Luna.

Here is another question regarding the moon. Does the moon rotate? In other words, does the moon spin on its axis? **Rotation is to spin as revolution is to orbit**. If I move around the room pretending that you (my class) are the moon, I am orbiting or revolving. The question again is, does the moon rotate while it is orbiting? Yes or no? Keep in mind that the moon always keeps it same face (hemisphere) pointed towards the Earth.

To help answer this question, I am going to put my arm perpendicular to my stomach, and I am going to revolve around the room keeping my same side positioned towards the class. If my arm which is perpendicular to my stomach completes one spin as I circle around the class, then I have rotated one time in one revolution. The moon keeps its same face (hemisphere) pointed towards the Earth as it orbits our planet. Look at the lower right sequence in the illustration below which shows the young lady orbiting the Earth while keeping the front of her body facing the Earth.

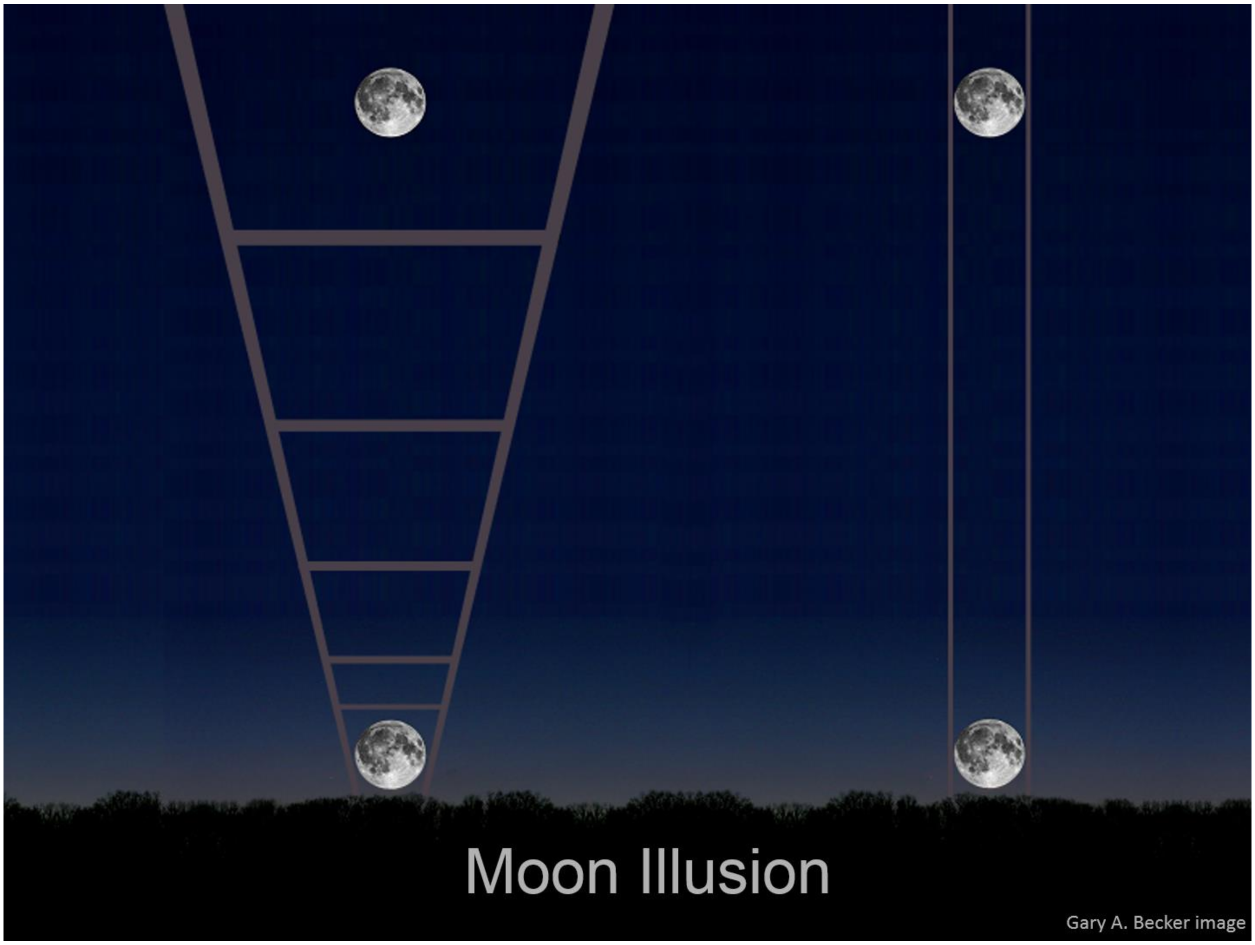


Gary A. Becker and Peason Education

During her revolution around the Earth, her face points in all directions indicating that she has rotated once in the same period of time as she has revolved around Earth. The revolution and rotation periods of the moon are synchronous (exactly the same), each completing in 27.3 days (the sidereal period), one rotation and one revolution.

Let me revolve around the room without rotating. Now I am doing what the young lady on the lower left of the illustration is completing. Tell me what it would be like to observe the moon if the moon did not rotate? A student responds that you would be able to see all parts of the moon. Yes! There would be no permanent near side, or far side. We would see the entire surface of the moon during the course of one lunar revolution. However, some of the moon would always be in darkness. It would take one year for an observer to map the entire surface of the moon.

Have you ever heard of the Moon Illusion? Did you ever see a nearly full or a full moon rising against a distant horizon? People will remark, "Oh, my gosh, the moon looks incredibly huge this evening." We have all seen this gigantic moon rise in the east. It just seems to stand out more if it is a full or a nearly full moon.



What I decided to do in this slide was to try to duplicate the Moon Illusion but with real images. Each moon is the same size right down to the pixel. To confuse the brain, I put an inverted Ponzo ladder into the image on the left. The ladder looks like it is moving towards infinity as it approaches the horizon. A normal Ponzo diagram is just the opposite with the ladder turned around to appear larger as the ladder is getting higher. To see the Moon Illusion, I want you to look in the middle of the ladder and then look up and down at the two moons. You may have to scroll a little with your computer mouse. You will also have a greater difficulty seeing the illusion if you look at the picture at an angle. The lower moon on the left should look a little bit bigger than the upper moon on the left. On the right I'm simply trying to show you that the two moons are indeed the same size. They are the same size as the two moons are on the left with the inverted Ponzo ladder.

The Moon Illusion is a psychological dysfunction between the eye which is not seeing anything differently, and the brain which has its own set of rules when comes to objects on the horizon at great distances. If I drew a dome over a person's head, all parts of the dome would be equally distant. However, humans are constructed mentally to think of the sky as a flattened dome over one's head. The brain thinks the zenith (directly overhead) is closer to you than the horizon. The eye however, looks at the moon when it is on the horizon or high in the sky and sees it as the same size.

There is no difference in the size of the moon on the horizon or high in the sky. In fact, what you can do is take a dime (10 cents), and hold it in front of the rising, nearly full of full moon that looks so big in the sky. Then wait a few hours until the moon has gained some altitude as the Earth continues to rotate underneath it. Take the same dime and put it over the moon. You will notice that there is no difference in the amount of moon obstructed. No matter where the moon is in the sky, the moon always is viewed as the same size. Because the brain thinks that the moon is farther away on the horizon, but the eye sees it as the same size, the brain makes the moon look bigger when is on the horizon. The same situation is true for the constellations as they approach the horizon. They will also look bigger because of this same eye-brain confusion. So, the next time you are driving along to some destination and see a nearly full moon rising in the east, pull over if you can and see how much bigger the moon actually looks. Then go about your business for a couple of hours. Afterwards, revisit the moon when it is higher in the sky, and you will see how much smaller the moon appears to have become. You will have partaken in the Moon Illusion.

What is a blue moon? Is the blue moon really blue? A blue moon happens when a full moon occurs twice in the time period of the same month. The second full moon of a particular month is called the blue moon. Blue moons occur about once every two and a half to three years so there can be a substantial amount of time that occurs between blue moons. This has also led to the concept of "once in a blue moon," which means not happening very often. In the year 2020 there were two full moons in October, on the 1st and on Halloween, the 31st. The second full moon of October was a blue moon. Blue moons do not look blue. In fact, when they rise, they probably have a yellowish or orangey tint because of the greater amount of atmosphere that the moonlight must penetrate. Add air pollution into the mix and the moon may even appear reddish. Some folks call this a blood moon but that term is more commonly used for lunar eclipses, when during totality, the moon may take on a distinctive, reddish hue.

I have just given you the more modern definition for a blue moon. The original definition was introduced by the *Maine Farmers' Almanac* in 1937. The *Maine Farmers' Almanac* gave ecclesiastical (religious) names to each of the month's full moons. If four full moons occurred in a seasonal three-month period, the calendar of named full moons would no longer coincide with the church calendar.

Think of it this way. You want to have a full moon, which has a religious name associated with it, and it also occurs at a certain time or season of the year. Examples might be the Easter Moon, Lenten Moon, or Yule Moon. But what happens if in the springtime you have a three-month period that contains four full moons. If you just continue using the moon names in their correct order, the Easter Moon will start to occur one month before it should actually happen, and that moon will no longer coincide with Easter. The full moon names will no longer be synchronized with the time of the year or with the calendar.

Think of the blue moon as a leap moon. Leap year day corrects the calendar and brings it into synchronization with the sun. The Blue Moon corrected the church's full moon calendar by not being counted, by being dropped as a moon that had no religious significance.

Every 19 years, January has a blue moon. If that occurs, there will be no full moon occurring in February because the phase period of the moon is 29.53 days. The best that February can muster is 29 days which is still short of a complete lunar phase cycle. March, therefore with 31 days, like January, must have a blue moon too.

You may be surprised to learn that the full moons of other months also have names. These do not come from the *Maine Farmers' Almanac*. Here they are: *January*—Old Moon, or Moon After Yule; *February*—Snow Moon, Hunger Moon, or Wolf Moon; *March*—Sap Moon, Crow Moon, or Lenten Moon; *April*—Grass Moon or Egg Moon; *May*—Planting Moon or Milk Moon; *June*—Rose Moon, Flower Moon, or Strawberry Moon; *July*—Thunder Moon or Hay Moon; *August*—Green Corn Moon or Grain Moon; *September*—Harvest Moon or Fruit Moon; *October*—Hunter's Moon; *November*—Frosty Moon or Beaver Moon; *December*—Moon Before Yule or Long Night Moon. Now, the next time the moon is full, you may see it in a new light or at least call it by its rightful name.

Reasons for the Seasons

Next on the list of things I would like to complete is a discussion and demonstration of the seasons. First, I want to show you a short section of the video that got Harvard educators scratching their heads because their graduates and teachers were unable to explain correctly why Earth had seasons.

What are the misconceptions associated with the seasons? People think that distance from the sun has everything to do with the seasons. Distance plays almost no role in the seasons. There is also an interesting explanation about the phases of the moon given by a Harvard professor in this video.

The video is started. Bells ring for Harvard's graduation ceremony.

Narrator: Despite a lifetime of the very best education, students in our classrooms are failing to learn science. Many of these students will graduate from college with the same scientific misconceptions that they had on entering grade school. To test how a lifetime of education affects our understanding of science, we asked these recent graduates some simple questions in astronomy. Consider, for example, that the causes of the seasons is a topic taught in every standard curriculum.

Student One: Okay, I think the seasons happen because as the Earth travels around the sun, it gets nearer to the sun, which produces warmer weather, and gets farther away which produces cooler weather and hence the seasons.

Student Two: How hot it is, or how cold it is, in any given time of the year has to do with the closeness of the Earth to the sun during the seasonal periods as Earth goes around the sun.

Student Three: The Earth goes around the sun. And it gets hotter when we get closer to the sun and it gets colder when we get further away from the sun.

Narrator: These graduates like many of us think of the Earth's orbit as a highly exaggerated ellipse (oval). Even though the Earth's orbit is very nearly circular, with distance producing virtually no effect on the seasons. We carry with us the strong incorrect belief that changing distance is responsible for the seasons.

Student One: I took physics, planetary motion, and relativity and electromagnetism and waves.

Student Two: I never really had a scientific background whatsoever. And I got through school without having it. I've gotten very far without having it.

Student Three: I had a quite a bit of science in high school. Through physics first year and two years of chemistry…

Narrator: Regardless of their science education, 21 of the 23 randomly selected students, faculty, and alumni of Harvard University revealed misconceptions when asked to explain either the seasons, or the phases of the moon.

Student Four: When it further away from the sun, then it gets colder.

The next person interviewed is a Harvard professor. Tell me what he's talking about?

Professor: The Earth's position interferes with the reflection of the sun against the moon…

I don’t want to get too critical here. If I was picked at random and asked a question far removed from my discipline, I might goof it up to.

The professor got phases of the moon mixed up with a lunar eclipse, which is the full moon going into and out of the Earth’s shadow. The phases of the moon are created as the moon revolves around the Earth, revealing different parts of the near side of the moon reflecting sunlight as the moon cycles through day and night.

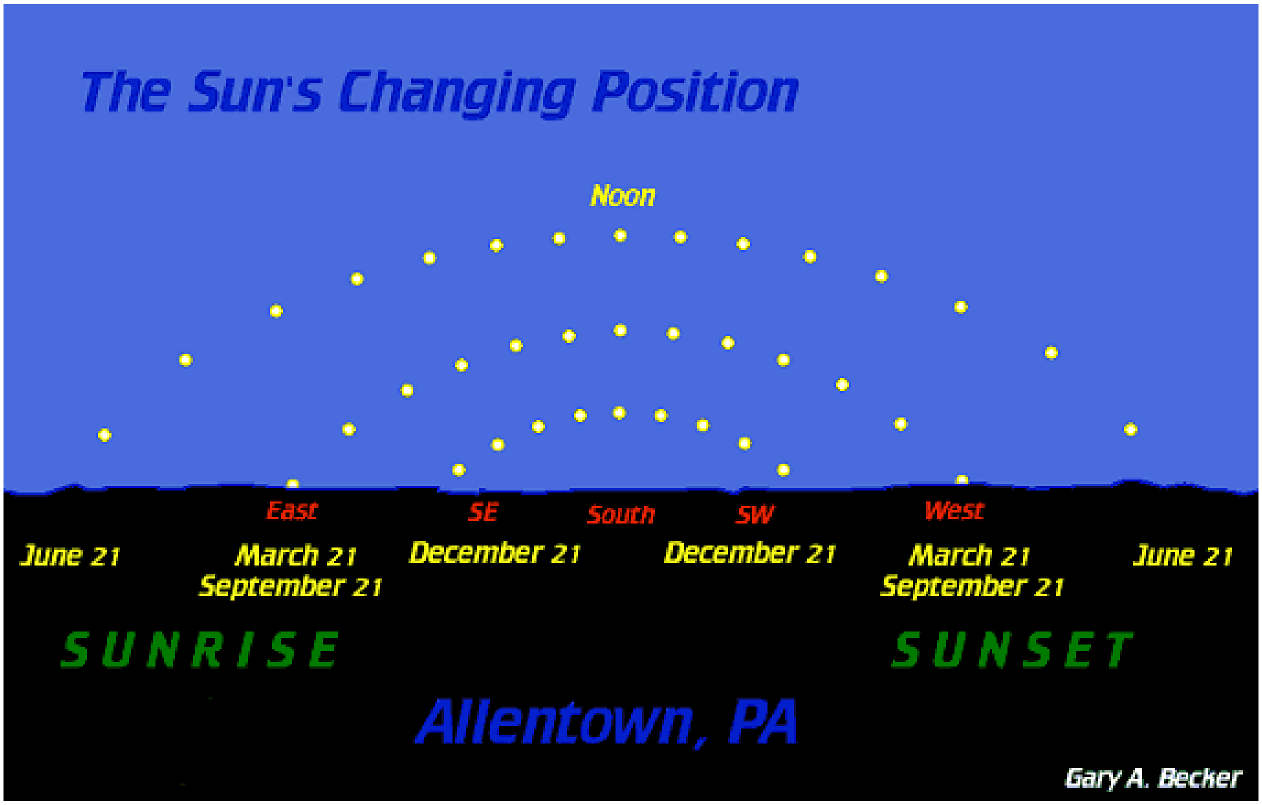
THE SEASONS

Most people believe that the seasonal variations that we experience are the result of our changing distance from the sun. Nothing could be farther from the truth. Although the Earth’s distance from the sun varies by about three million miles, we are closest to the sun in winter (January 2-3) and farthest from our daystar during the summer months (July 2-3-4), just the opposite of what would be normally expected. The seasons are really the result of changes in the amount of solar energy which is being received at the Earth's surface. These energy changes come about because the Earth’s axis is tilted in relation to its orbital plane which is called the ecliptic.

The Earth's axis is the imaginary line about which our planet rotates. The measure of Earth’s axial tilt is referenced from the perpendicular to the ecliptic. It is generally stated in the following manner. The Earth’s axis is tilted 23-½ degrees from the perpendicular to the ecliptic. Earth’s axis pointing in the same direction is another factor responsible for creating seasonal changes which is often neglected in explanations of the seasons.

Currently the axis is pointing in the direction of the North Star, also called Polaris. This is why Polaris represents the focal point in the sky as the stars pivots because of the Earth's rotation. Expressed in another way, the ecliptic is tilted to the plane of the Earth's equator by 23-½ degrees.

Our orbital motion makes the sun move eastward among the stars. Our axial tilt also causes the sun to move northward or southward with respect to the equator or celestial equator. The sun shines directly over the Tropic of Cancer, (23,5 degrees north latitude) on the summer solstice, the equator on the equinoxes (0 degree), and the Tropic of Capricorn (23.5 degrees south latitude) at the time of our winter solstice. This yearly cycle can be easily monitored as the seasons progress as illustrated in the picture below.



1. **<u>The altitude of the sun changes</u>:** The sun reaches its highest position above the horizon at local noon each day. In Allentown, PA or for that matter the Lehigh Valley, when the sun is at its most northerly position with respect to the equator, its altitude at noon is at an extreme of 73°. This occurs on the first day of summer. In Allentown, the sun is never directly overhead. On the first day of winter, the sun is as far south of the equator as it can be found, and it achieves its minimum altitude of 26° at noon as seen from the city.
2. **<u>The duration of daylight changes</u>:** The longest day of the year occurs for the northern hemisphere when the sun is at its most northerly position with respect to the equator. This marks the first day of summer. In Allentown, the sun rises in the northeast taking approximately 15 hours to cross the

sky before setting in the northwest. The path that the sun takes from rising to setting is longest at summer solstice. Therefore, the day must also be at its longest because the earth rotates at a uniform rate of 15 degrees/hour. When the sun is at its greatest deviation south of the equator, the day is the shortest. This marks the beginning of winter for us, but summer in the Southern Hemisphere. In Allentown the sun rises in the southeast, and about nine hours later, it sets in the southwest.

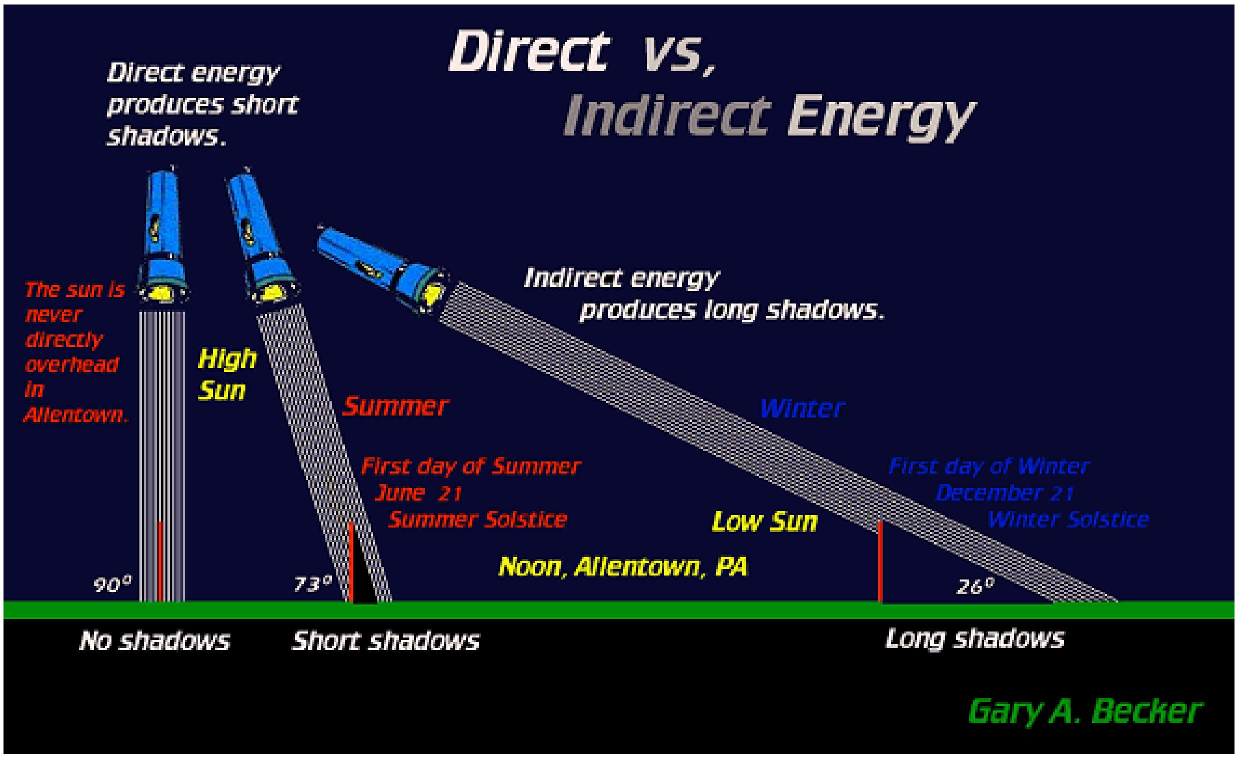
3. **<u>The positions of sunrise and sunset change</u>:** For observers in Allentown on the first day of summer, the sun rises as far to the north of east and sets as far to the north of west as it can for the year. The sun is positioned at its maximum extreme north of the equator. When the sun is positioned as far to the south of the equator as it can move, on the first day of winter, it rises as far to the south of east and sets as far to the south of west as it can for that location. The sun, therefore, changes its daily rise and set positions with respect to the horizon. A mistake that students often make is to imagine the sun rising in the southeast, but setting in the northwest. For this to occur the sun would have to travel from its winter position below the equator and move northward over the interval of one day to set in its summer position north of the equator a condition that takes six months to transpire between solstices.

In winter, the northern hemisphere leans back from the sun. The daily duration of sunshine is restricted, and the sun is lower at noon. The sun's energy strikes the ground at a shallower angle, and thus less energy is received per unit area. The temperatures generally become colder. In summer, the northern hemisphere is tilted toward the sun. Not only is the daily duration of sunshine longer, but the sun also climbs to a higher altitude in the sky, so that its energy strikes our position more directly, and we receive more energy per unit area. All of these effects result from the tilt of Earth's axis and its consistent pointing direction.

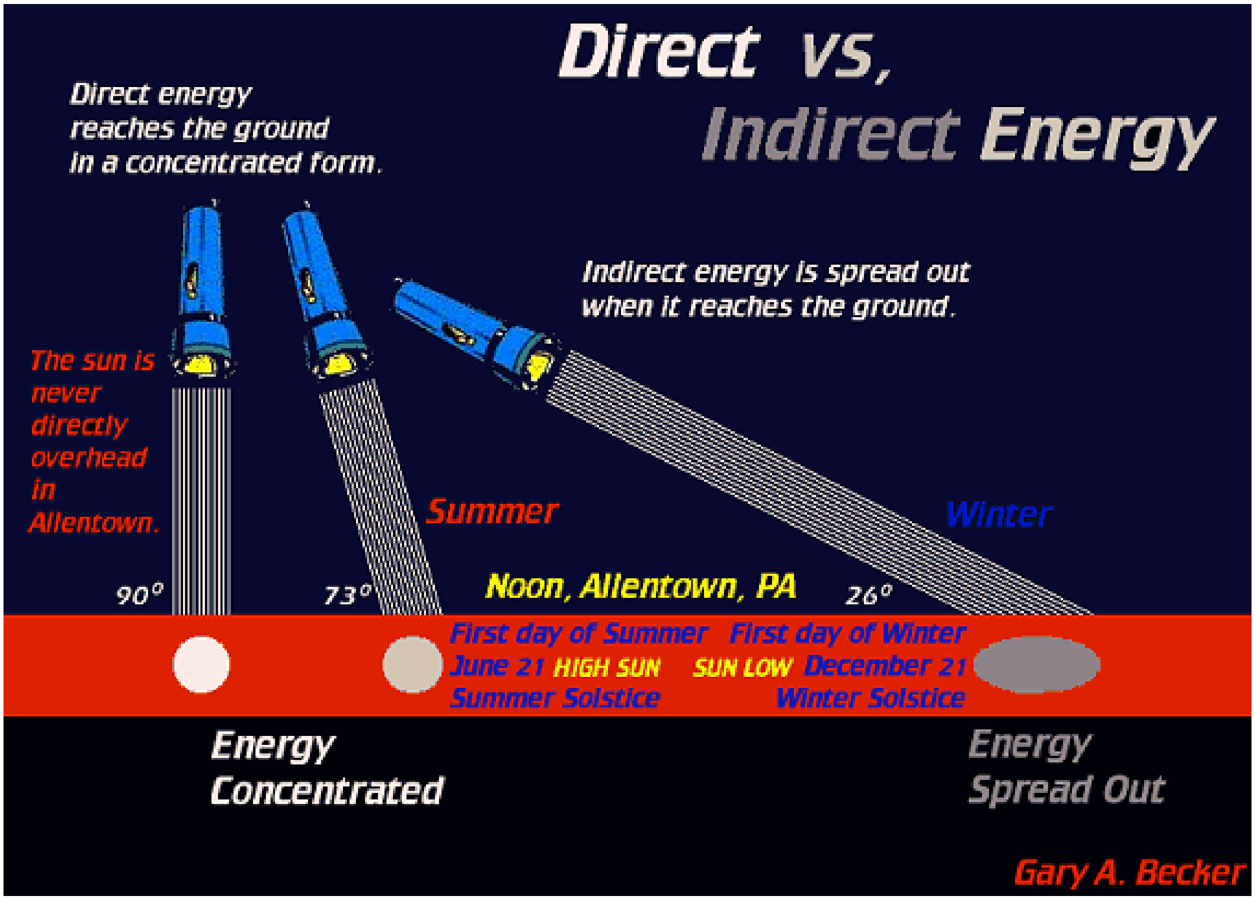
The seasons are a result of the Earth's axial tilt and the Earth's axis pointing in the same direction. The Earth's axis is not perpendicular to the plane of its orbit which is called the ecliptic. You can memorize that, but it is certainly easier if you give it some thought and try to understand it so you can explain it to others.

Because the axis of the Earth is tilted, we observe the sun, making three distinct changes over the course of a year. As an example, if I said to you, the length of time that the sun is visible in the wintertime versus the length of time that the sun is above the horizon in the summertime. You would state that the days of the winter are shorter, much shorter than the days of the summer. Can you tell me what time of the year is the season of the long shadows? This is a literary term associated with Native American people. When do we have long shadows for all of the time the sun is above the horizon: in the summer; in the winter; all year round?

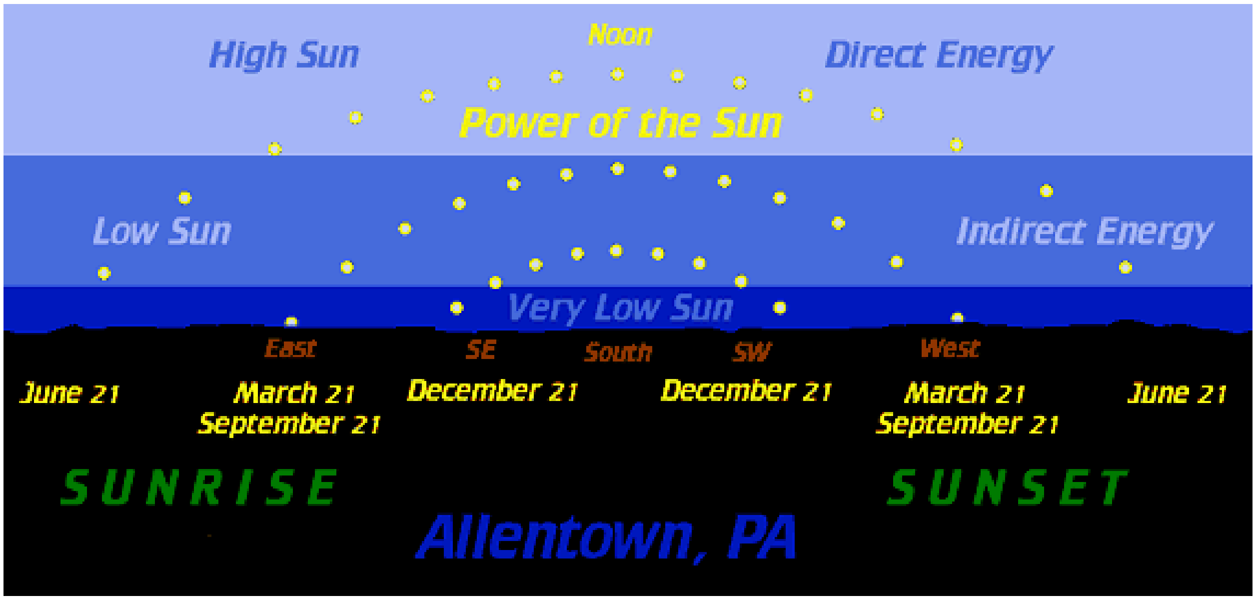
The long shadows happen when the sun is low in the sky; short shadows occur when the sun is high. The picture on the next page illustrates with a flashlight the concepts of short shadows, long shadows, and no shadows. The best that the sun can do, altitude wise for the summer solstice for the Lehigh Valley is 73 degrees. The winter solstice sun only reaches to a noontime altitude of 26 degrees, a difference of 47 degrees or twice the axial tilt of the Earth. During each season the sun changes its noontime altitude by 23.5 degrees everywhere in the world. From summer solstice to winter solstice, two seasonal changes, the noontime sun decreases in altitude by a total of 47 degrees.



Study the diagram using the flashlights in the image. In the summertime, the sun is very high in the sky, producing short shadows. In the wintertime, the sun is always near to the horizon. We have long shadows, created by the low altitude of the sun in the sky. The time of the long shadows represents the period when the days are protracted or very short. It is the time of darkness because the sun is low in the sky all day long.



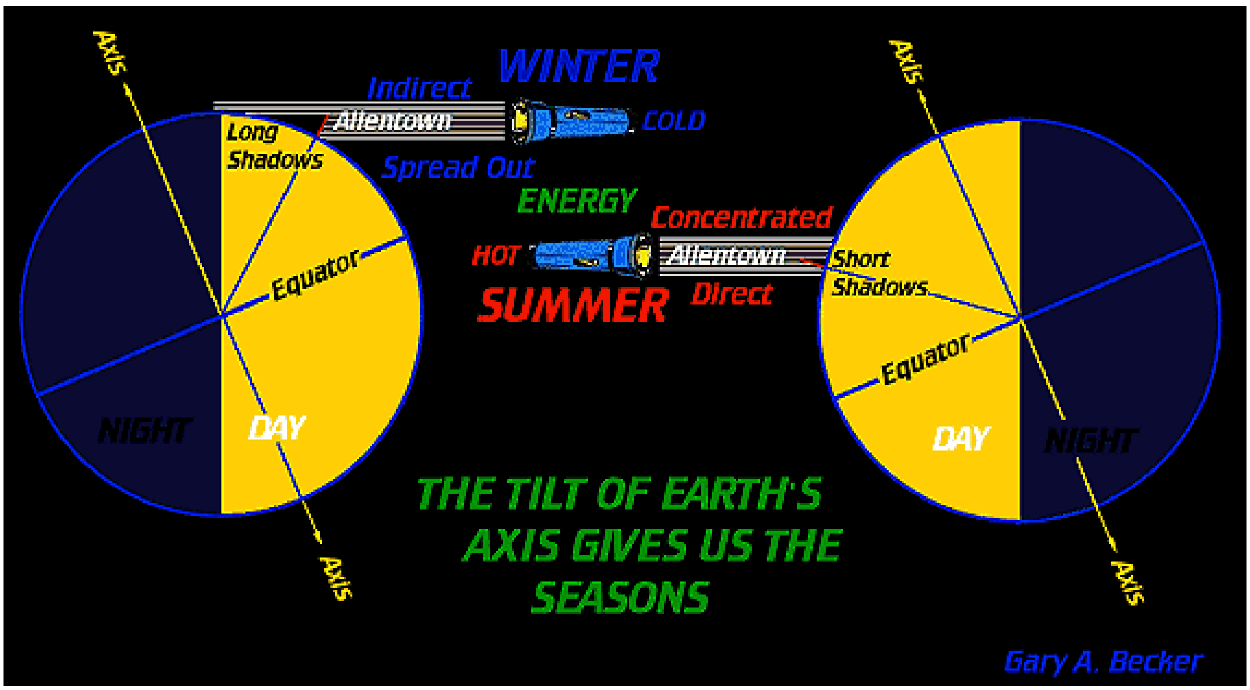
In the above picture we see the same three flashlights that were portrayed in the last image; only in this rendition, the intensity of light on the ground is being shown. The energy of the sun is most concentrated, most **direct**, when the flashlight is in a vertical position, but very little potency is lost when the 73-degree noontime altitude of the sun is illustrated for the Lehigh Valley. Contrast that with the winter solstice, **indirect** energy example. The sun is only 26 degrees above the horizon for the Lehigh Valley. In winter the amount of energy per unit area is decreased **(indirect energy)** and so is the amount of time the sun is above the horizon—nine hours. Conditions must cool. In the summertime, concentrated **(direct)** energy and the visibility of the sun for a much longer period of time during each day, 15 hours, creates much warmer conditions.



In the picture above we are seeing the three effects of the seasons for the Lehigh Valley. Over the time period of one year the sun changes its rise and set positions, its altitude at noon, and the amount of time that the sun is above the horizon. The spaces between each sun represents one-hour intervals of time except for the summer and winter solstices where the space from the horizon to the first and the last suns represents 30 minutes. Count the time that the sun is above the horizon at these extremes (solstices) and midpoints (equinoxes) position of the year. The summer solstice sun is above the horizon for 15 hours, the winter solstice sun is visible for 9 hours, and the equinox sun crosses the sky in 12 hours.

Here is a curious situation for the positions of sunrise and sunset at opposite times of the year. It is the same for every location on Earth. The winter solstice sunrise location is 180 degrees opposite the summer solstice sunset positions. Summer solstice sunrise is opposite to winter solstice sunset.

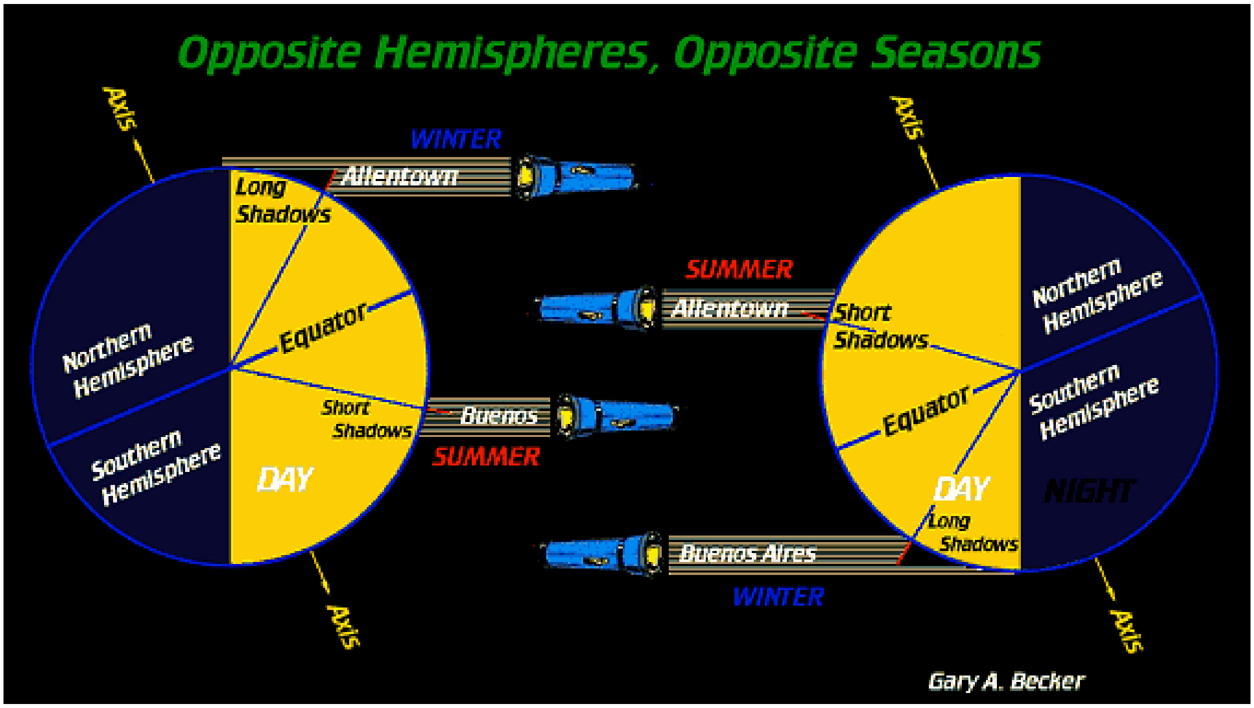
Let us examine the words equinox and solstice. Both words are derived from the Latin. In the word equinox you can almost hear the words equi-equal and nox-night; equal nights and equal days at the time of the equinoxes, usually around September 22 (autumnal) and March 20 (vernal). The word Sol is contained in solstice and that is also from the Latin meaning sun. The whole word means sun still or sun standstill. The times of the solstices are usually June 21 and December 21. The rise and set positions of the sun are opposite to each other for opposite solstices.



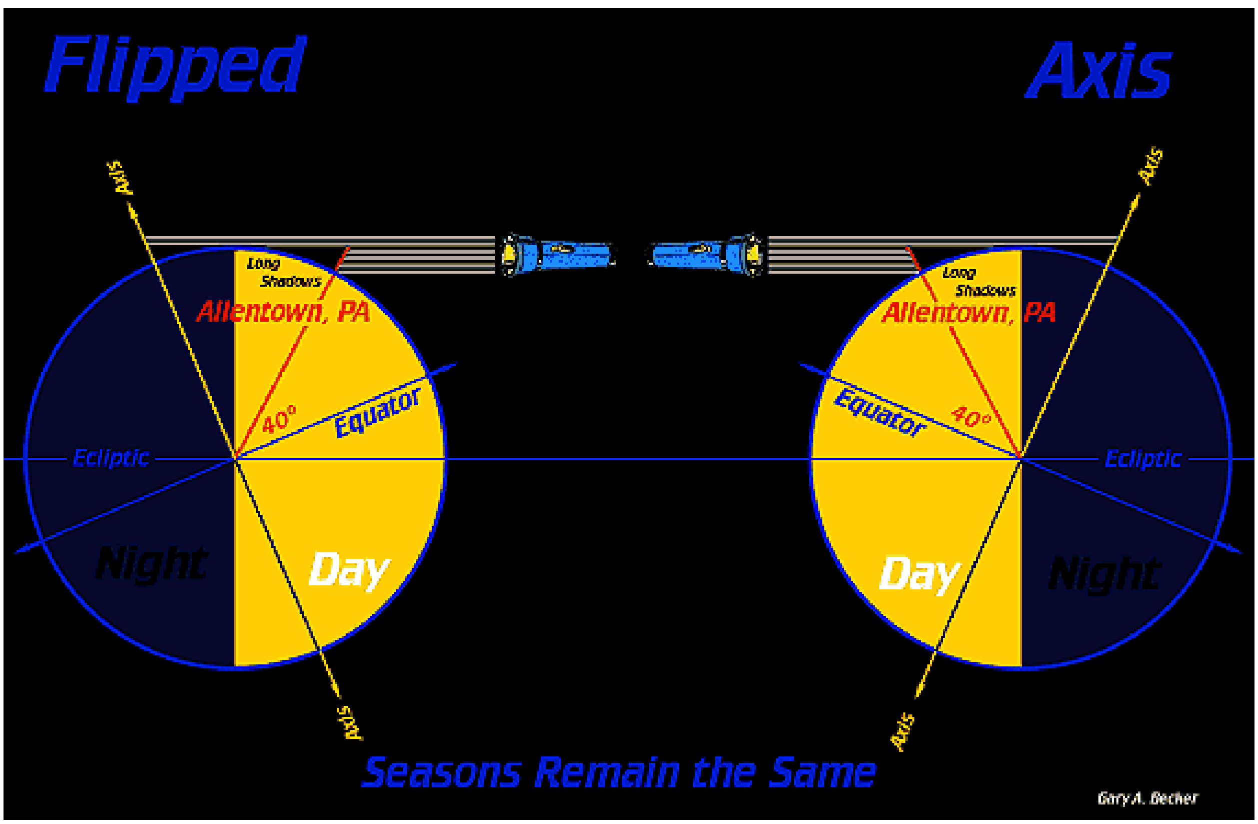
In the picture above, note how the tilt of the Earth's axis and the fact that the axis is pointing in the same direction as Earth orbits the sun allows the sunlight to create long shadows (left) in the wintertime for the Lehigh Valley and the short shadows during the summer high sun.

We use the ecliptic as the reference plane of the solar system. It is the plane created by the Earth's revolution around the sun. When we talk about the axial tilt of the Earth, we reference it to the perpendicular to the ecliptic. We say that the axis is tilted by 23.5 degrees from the perpendicular to the ecliptic. We could also say that the Earth's axial tilt is 66.5 degrees to the ecliptic, but this notation is never employed, so it will not be used here. This tilt and the condition that the axis points in the same direction are responsible for the change in the sun's altitude, the change in the length of day and night, as well as the change in the rising and setting locations of the sun. These are the three effects of the seasons and not their causes. The seasons are created by the axial tilt of the Earth and the axis pointing in the same direction as Earth revolves around the sun.

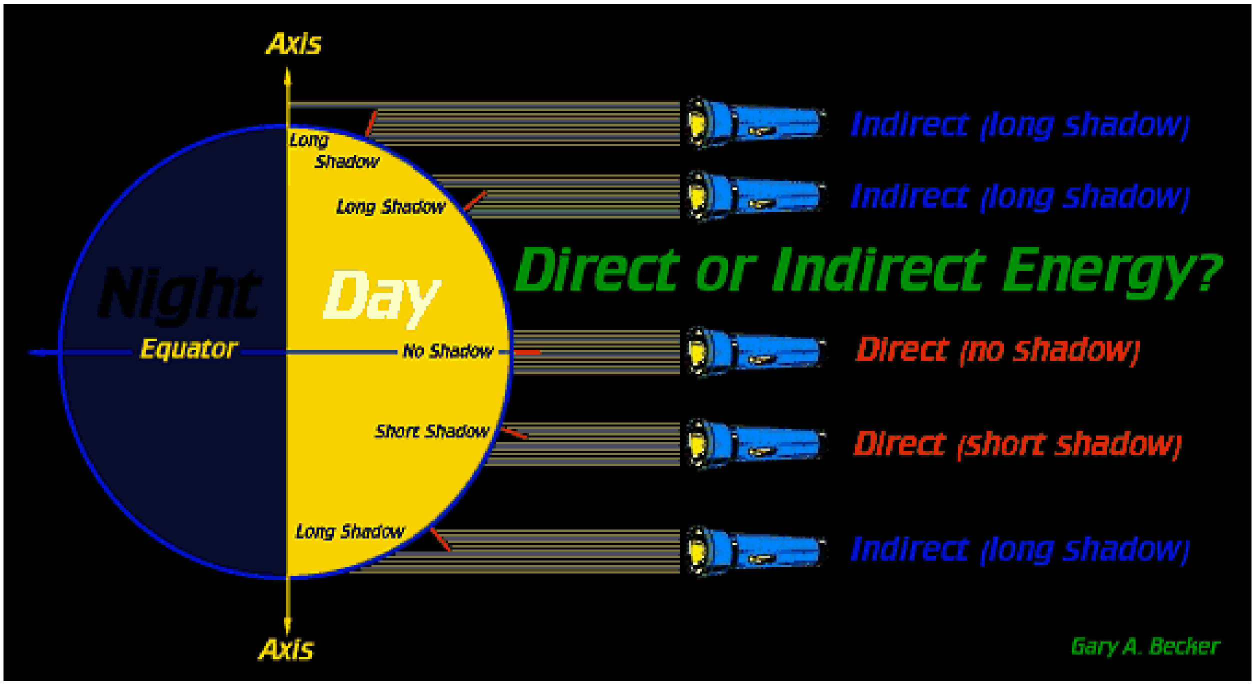
With regard to the axis pointing in the same direction, it intersects the sky (celestial sphere) within one degree of the North Star. The north celestial pole defines the precise location to where the axis points, causing the heavens to pivot around this location, as well as the south celestial pole in the Southern Hemisphere. If the axis moved or precessed rapidly, we would have a speedy change of the pivot point in the sky around which the heavens turn, quickly replacing the North Star (Polaris) with new stars around which the axis would be pointing. The North Star is the visual pivot point during the winter, spring, summer, and fall, so the axis must be pointing in the same direction all year round. Although the Earth completes one precession cycle in a 26,000-year period, for all practical purposes during a lifetime, the location defined by where the axis points remains a fixed position in the heavens.



Note how the seasons at the same time of the year are opposite to each other in opposite hemispheres.



Another major misconception regarding the seasons is that they are caused by the Earth's axis flipping back and forth. The concept of flipping is really the conical wobbling of the Earth axis known as precession. This is a real effect with takes place over a 26,000-year interval, but not over the time interval of one year. In the illustration above, it will be noted that the seasons would not change if this actually occurred. In the picture, Lehigh Valley would be immersed in a perpetual season of winter.



Finally, if the axis of the Earth were not tilted but perpendicular to the plane of Earth's orbit and always pointing in the same direction, the seasons would not change for any location on the planet. In places where the sunlight was direct, summer would always prevail. Mid-latitudes conditions would be more spring like. In high latitudes, winter would be the continuous all year round.

In the class video, I demonstrate these same concepts with a large Earth. It is well worth watching.

March 6, 2021
March 5, 2021
February 26, 2021