Joan and John Evans Legacy Sundial

PreK-Adult "Edutainment" Activities for Families and Educators

by Carol Evans

Why study sundials? A sundial can provide an introduction to a variety of subjects:

- **Astronomy**: The observation of the apparent motion of the sun is a good starting place to understand the Earth's rotation and orbit around the sun. The concept of frames of reference (what we observe from Earth, and how it looks when viewed from space) is a skill needed for understanding topics of astronomy.
- **Geography:** Making and using a sundial helps to provide a better understanding of latitude and longitude, the poles and the equator. It gives a physical sense of these abstract concepts.
- **Ancient Cultures:** Ancient peoples, from Stonehenge to the Aztecs and Mayans to the Ancient Pueblo peoples (ancestors of the Hopis and Zunis) found ways of marking the position of the sun and using that knowledge to predict the seasons.
- **Art:** Sundials can take many forms. Once an artist understands the essential elements of making a sundial, they can create beautiful sculptures that are functional.
- **History:** The measurement of time is basic to science and exploration. As humanity developed increasingly accurate ways of measuring time, we have been able to discover more about the world. Navigation was revolutionized by the invention of a mechanical clock that can function on a rolling ship. Sailors could not determine longitude without an accurate measurement of time. The invention of a clock powered by a spring ushered in the age of exploration.

SUGGESTED LEARNING ACTIVITIES:

Pre-Kindergarten to Early Elementary: Shadow Play

I have a little shadow that goes in and out with me,
And what can be the use of him is more than I can see.
He is very, very like me, from the heels up to the head;
And I see him jump before me, when I jump into my bed.

The funniest thing about him is the way he likes to grow –
Not at all like proper children, which is always very slow;
For he sometimes shoots up taller like an india-rubber ball,
And he sometimes gets so little that there's none of him at all.

In this poem Robert Louis Stevenson remembers the wonder of a child observing his shadow. This sense of wonder is at the heart of science.

Here is a simple activity to encourage young children to observe their shadow and think about what creates a shadow: https://stardate.org/sites/default/files/pdfs/teachers/ShadowPlay.pdf

Supplement this by playing shadow tag. Instead of tagging a person, the person who is "it" tries to step on the shadow of someone. The game is more difficult at midday when shadows are shorter.

Elementary: Make A Paper Sundial

There are templates available to make simple sundials with paper. A template for a horizontal sundial (the type that is typically placed in gardens) from "Astronomy for Thinkers" can be found at the link below. Download the template for "Latitude 40° N"
https://www.astronomyforthinkers.com/downloads/simple-horizontal-sundial/

Have the students cut out and assemble the template, then tack each assembled template to a horizontal surface in the sunlight. The teacher should mark the north-south line beforehand to orient the sundials correctly. Alternatively, for an approximate orientation, just turn the sundial until it reads the correct time and tack it down firmly. Then check throughout the day. It should continue to give the correct time.

Elementary and Older: Record the Sun's Apparent Motion by Marking the Shadow of a Vertical Post

Tape a piece of paper unto a piece of cardboard and stab a large nail vertically into the center. Make a straight line from the nail outward – This will give you a reference for the starting point, and will help later to make observations another day with the same alignment. Place this on a flat surface in full sun in a place that receives sunlight most of the day. For the starting time, line up the shadow of the nail to the line you have drawn and mark where the top of the shadow is. Observe and mark the end of the shadow at intervals of half an hour for several hours. Save these to add future observations.

Discussion: What is the pattern? As the sun moves toward the west the shadow moves from west to east. How can we use this knowledge to tell time? Can you have an idea of what time it is by looking at your shadow? Can you have an idea of direction by looking at your shadow?

Several weeks later, repeat the observations. Start at the same time as before, with the shadow again lined up with the line. You might want to use a different color of pencil to distinguish the observations from those made on the first day. Record the end of the shadow at the same times as previously.

How is it different this time? If this is done in first semester, going towards winter, the sun will be lower the second time which will make a longer shadow. (Conversely, if you do this experiment in the spring, the sun will be higher as it moves toward summer, and the shadow will become shorter.) As we go from autumn into winter, the sun is lower in the sky. This is why it is colder in the winter. As we move towards spring, and the sun gets higher in the sky, the more direct sunlight heats up the land.

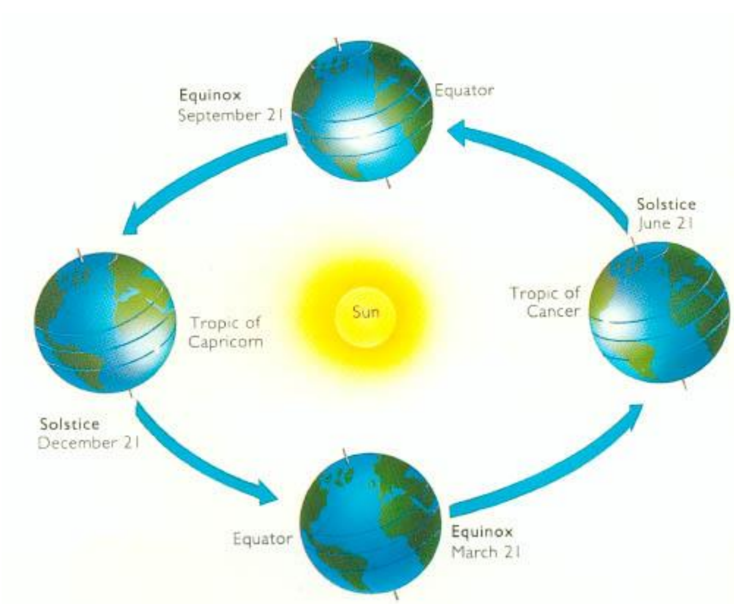
Elementary and Older: Visit The Joan and John Evans Legacy Sundial

Once students have an idea of the sun's path during the day and how it changes with the seasons, they are prepared to visit the analemmatic sundial. Give each student a chance to stand on the correct month and show them how to read the time. Note that for daylight savings time, it is necessary to add one to the hour shown by the sundial.

Notice that the hour markers are on an ellipse, a "squashed circle." Why is that? Why do you stand in a different place according to the month? In June, the sun is at the highest, and the place to stand is closest to the front – when your shadow is the shortest. December is when the sun is lowest in the sky, your shadow is longest, and so the December marker is farthest back. A sundial has to be set a certain way for each location.

In ancient times, people watched the skies and marked the position of the sun (or a shadow) each day for years and they saw that the pattern repeated each year. After years of observation, they could mark the time of day and know when the seasons would change. Over hundreds of years, after a great many people thought about these observations and patterns, they began to understand that the sun's path across the sky changes throughout the year because of the earth's tilted position, its daily rotation, and its annual orbit around the sun. Having that knowledge makes it possible to calculate the position of the sun at any given time and place on the earth, and to make a sundial for that place without having to do years of observation at that place. This sundial was designed using calculations of the sun's position at the specific location of Janesville on the surface of the earth (the specific latitude and longitude of Janesville). The contractor followed the design that was created on paper to place the markers – and it works!

Elementary and Older: <u>Demonstrate the Movement of The Earth</u>



Using a globe to represent the earth and a flashlight to represent the sun, demonstrate how the movement of the earth produces day and night and the seasons. Most globes are mounted at a 23 ½ degree tilt. Putting a marker (push pin) at your location on the globe will help the students envision the movement of the earth in relation to the sun.

To begin, have the earth in the position of the equinox, tilted with the South Pole to the right and the North Pole to the left, and the light shining directly on the equator. Spin the globe counterclockwise to show how the light moves across the globe from east to west, making day and night. What would it look like to a person sitting on the Earth at the marker? Notice how the light shines directly on the equator and just tangentially on the poles. The sun is directly overhead at the equator on the equinox, and just on the horizon at the poles. The more direct the sunlight, the hotter the climate.

As well as spinning on its axis once a day, the earth also orbits around the sun during the course of a year. While spinning the globe, begin walking counterclockwise around the light. A quarter of the way around, the North Pole is pointed towards the light. This represents the summer solstice. In the northern hemisphere, the sun will be at the highest in the sky, so we will feel the most heat. Also, there are more daylight hours, which means more time to receive the sun's heat. Notice that as the earth spins, now the North Pole is in daylight all the time but the South Pole is in the dark all the time.

Continuing in the orbit, another quarter of the way around comes to the autumnal equinox. This is similar to the vernal (spring) equinox on the other side. All places on the earth receive equal time of daylight and nighttime at each equinox. During the autumnal equinox sun is setting on the North Pole and rising on the South Pole. During the vernal equinox the sun is rising on the North Pole and setting on the South Pole.

The next quarter turn around the sun comes to the winter solstice, with the south side of the globe getting the lightest. This represents winter in the north, when the sun is low and the nights are long.

Here is a two-minute YouTube video showing the sun's path one day each month at New York.
https://www.youtube.com/watch?v=adJPV-sz5AI

While it is true that the sun rises generally in the east and sets generally in the west, you can see in the video that during the summer months it rises in the northeast and sets in the northwest. During the winter months, it rises in the southeast and sets in the southwest. This is because the axis tilts more towards the south during the winter months, so we see the sun in a more southerly direction. The video is a simulation made using the free, open-source planetarium that you can find at www.stellarium-web.org

You can use the stellarium website to find a map of the sky at any time and place. Students who are interested in astronomy could investigate the stellarium website or app on their own time. If you are able to take the class on a nighttime field trip to see the stars, the stellarium software is a great help.

Fifth Grade and Older: What Does the Sun's Path Look Like at The North Pole?

How can it be that the Earth's poles have six months of daylight and six months of night? What does this look like? (Let students give their ideas.) Demonstrate with the globe…. At the North Pole, every direction is south. If you stand exactly on the North Pole, the earth is rotating under you counterclockwise. The sun and stars appear to circle clockwise around you. Shine the flashlight on the globe at equinox position. What does a person standing at the North Pole see? The light is just hitting the poles horizontally. The vernal equinox (spring equinox) is the time of sunrise at the North Pole (and sunset at the South Pole). On that day, the sun is just on the horizon. For the next several days, the sun will be seen circling around the horizon, with a little more of the sun visible each day. It will spiral up, circling around, until it reaches 23 ½ degrees above the horizon on the summer solstice. After June 21st, it will begin to spiral down again until sunset on the autumnal equinox.

Middle School: Make an Equatorial Sundial

The website stardate.org has a template that includes a dial face and a latitude strip for making a simple equatorial sundial. (As well as lots of other good science lessons.) The only materials needed are a printout of the provided template, scissors to cut out the template parts, a drinking straw, glue, tape, and a pen or pencil. The trickiest part is determining north and mounting it at an angle tilted from vertical by the angle of latitude. (See "Determine North" activity, above.) The cool thing is that once mounted correctly, the gnomon is parallel to the earth's axis. It gives a more physical sense of the earth's axis and rotation. https://stardate.org/sites/default/files/pdfs/teachers/EquatorialSundial.pdf

Middle School and High School: Latitude

Watch the video "Sundials and Latitude" https://www.youtube.com/watch?v=WXiakqRWcHc

There are various types of sundials. The type shown in the video is an equatorial sundial, which is tilted at an angle of the latitude. The analemmatic sundial is on the horizontal ground, but uses an ellipse instead of a circular disk. If you tilt a circular disk at the angle of the latitude and shine a light vertically on it, the shadow of the disk will form an ellipse, which gives the shape of the analemmatic sundial for that latitude. In the case of a horizontal sundial (which is the most common type for gardens), the gnomon that casts the shadow must be set at the angle of the latitude.

Have students calculate the maximum and minimum angle of the sun at solar noon for their latitude. Zero degrees represents the sun on the horizon, and 90 degrees is directly overhead. At the summer solstice the sun is directly over 23 ½ degrees north. For a location in the northern hemisphere, the maximum sun angle will be 90 – latitude + 23.5. (For example, at 42.5 north latitude, the sun angle will get up to 71 degrees above the horizon at noon on the solstice.) On the winter solstice, the sun will be at 23.5 degrees south. On this day, the angle of the sun at noon will be 90 – latitude – 23.5. (For our example of 42.5 degrees north latitude, the sun angle will only reach 24 degrees above the horizon.) These calculations are useful for many things, such as designing and installing solar panels or taking advantage of the sun in deciding the placement of windows when designing a house, among other uses.

Middle School and High School: Longitude and Time Zones

Watch the video, "Determine longitude" https://www.youtube.com/watch?v=b7yoXhbOQ3Y

You may want to have the students do the experiment shown in the video to determine your longitude. (This requires measurements to be done near noon. If you are on daylight savings time, solar noon will be closer to 1:00 than noon.)

A sundial corrects for longitude by lining up the mean solar noontime for that latitude to the meridian. In other words, the sundial must be rotated by the number of degrees away from the time zone longitude. For example, Janesville is at 89 degrees west longitude. The reference longitude for Central Standard Time is 90 degrees. Thus, the sundial should be rotated one degree clockwise.

Math question: How long does it take the earth to rotate one degree? The earth rotates 360 degrees in 24 hours, thus 360 / 24 = 15 degrees per hour. There are 60 minutes in an hour / 15 degrees = 4 minutes to rotate one degree. For each degree longitude, there is 4 minutes difference in solar time. (Since Janesville is one degree east of the CST longitude, this means that mean solar noon will occur 4 minutes before noon in Janesville.)

Middle School and High School: Solar Day and Sidereal Day

By definition a day is 24 hours long, but the earth actually takes about 23 hours and 56 minutes to make a full rotation (this is called a "sidereal day"). However, during the time it takes to make one rotation the earth has also moved along its orbit around the sun. This causes the sun to lag a bit behind from where it appeared in our sky the day before because the Earth had to rotate a little more for the sun to reach the same place as it did on the prior day. It takes about 4 minutes to rotate that extra bit to complete a "solar day". This can be calculated easily: It takes 365 days (one year) to move 360 degrees (one orbit) around the sun, so the earth moves in its orbit slightly more than one degree per day. It takes 4 minutes for the Earth to rotate on its axis by one degree (24 hours * 60 min per hour = 1,440 minutes per day / 360 degrees = 4 minutes).

The sidereal day is quite constant, but the solar day is a few seconds longer or shorter depending on the time of year because the earth moves faster or slower in its orbit. The time given on a sundial will differ from the time on a clock by as much as 16 minutes, depending on the time of year. The analemmatic sundial is not precise enough to notice this difference. A person's shadow is wide, and covers 15 minutes or more on the hour markers. A method used to accommodate the variation in day length is called the "equation of time". There are sundials that are very precise and, when corrected with the equation of time, will agree almost exactly with a clock.

Here is a graph of the equation of time

These videos help to explain the difference between sidereal day and solar day time and the resulting equation of time:
(446) THE EQUATION OF TIME - YouTube
(446) Equation of Time - YouTube

In the 17th and 18th centuries, when pendulum clocks existed but not pocket watches, people used a diptych sundial, a portable folding sundial. A diptych sundial has a gnomon (the vertical element that casts a shadow to tell the time) that folds down for carrying and is raised to the angle of the latitude of the location for use. It has a magnetic compass to orient the sundial towards north. On the inside cover is a chart of major cities with the correction for true north, the latitude (how high to raise the gnomon), longitude (to correct for the position within the time zone), and a chart of the equation of time correction by date. Here is a photo of the diptych sundial that John Evans owned.

This article and these videos explain the difference between magnetic north and true north:
Magnetic North vs Geographic (True) North Pole - GIS Geography,
(446) The Compass: True North vs Magnetic North - YouTube,
(446) Geographic (True) North vs Magnetic North - YouTube,

Middle School and High School: Determine North

Sure, you can just look at google maps, but the point is to understand what the cardinal directions mean. Ancient peoples all over the world were aware of east (birthplace of the sun), west, north, and south. There are several ways to find the cardinal directions. It is an interesting project to have groups of students determine north by different methods and compare the results. Here are a few ways:

1. Use a magnetic compass. The needle of a compass points to magnetic north, a spot in northern Canada. This is not the same as geographic (or true) north. The difference in the angle of magnetic north and true north is called the declination. You can correct the compass reading by looking up the value of declination at https://www.ngdc.noaa.gov/geomag/calculators/magcalc.shtml Fortunately, for Wisconsin the

difference is only a few degrees. In Washington State or British Columbia, the declination can be 20 degrees east of true north. Likewise, for Maine or Nova Scotia it can be up to 20 degrees west of true north.

2. When the sun is highest it is to the south, and the shadow of a vertical post will point north. Place a stick vertically into the ground and mark the length of the shadows it casts in 15 min intervals around midday. The shortest shadow will point very close to north. There is a slight difference because at certain times of the year the sun will be slightly to the east of the meridian at its highest point and at other times slightly to the west of the meridian at other times of the year. (This is one of the factors of the Equation of Time, and the difference can be at most 5 degrees.)
3. Near solar noon, the sun’s position is moving straight east to west so, when marking the stick’s shadows in 15 min intervals the ends of the shadows will create a line from west to east. Draw a straight line connecting the ends of the shadows. North will be perpendicular to this line. This article and these videos show how to use the stick shadow method:
   Find Your Direction With A Stick And The Sun (modernsurvivalblog.com)

   Find North Without a Compass: Shadow Stick Method - Bing video

   (446) Shadow Stick Method for Finding Direction - YouTube

   (446) Sun Compass Shadow Stick Method - YouTube

If you have the possibility of observing at night, finding Polaris (the “North Star”) is the most accurate way to find north. Here is a video explaining how to do so. (446) What's so special about Polaris, the North Star? - YouTube

High School: Draw A Sundial Template

The website of the North American Sundial Association has instructions for a graphical method to draw a sundial template. It requires careful measurement with compass and a protractor, but not complicated math calculations. This sundial could be made of paper. Once the template is drawn, it can be used for making a more permanent sundial. Designing and placing a sundial deepens understanding of the principles behind it.
https://sundials.org/index.php/teachers-corner/sundial-construction/154-banneker-drawing-a-dial5

High School: Passive Solar Design

Knowledge of the sun’s altitude over the course of the year is useful in the design of buildings that have low heating needs in the winter without getting too hot in the summer. The main idea is to place living areas on the south facing side of the building with large windows to receive sun during winter days, and place utility rooms and sleeping quarters on the north side with small, thermal windows. Large overhangs over the south facing windows protect from direct sunlight during the summer months. John Evans's son, Rich Evans, used John's formulas for passive solar design for his house in Pennsylvania. They have lived in the house for 25 years and have low heating costs. He cautions, however, that it is important to use insulated shades or curtains at night in the winter to prevent heat loss. Otherwise, there is a danger of losing more heat at night than you gain during the day. At any rate, it is wise to consider the sun's path when designing a house. Which rooms do you wish to receive the most sunlight and at what times and seasons?

This video gives a good summary of the sun's path, and introduces the basics of using the sun's position to optimize solar panels or passive solar heating: https://www.youtube.com/watch?v=OR8EQ0DWpPw

Students who have had a course in trigonometry can combine it with calculations of the sun's path to find how much sunlight will fall through windows at different times of the year. Here is an example of a math problem:

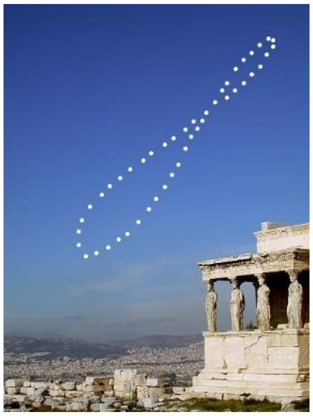
Sue's house, at latitude 42 degrees north, has a living room on the south face with a sliding glass door leading to a patio. The glass door is six and a half feet high. At eight feet above the patio there is a second-floor balcony that is 9 feet wide. How much of the glass door will receive sunlight at the winter solstice? At the equinox? At the summer solstice?

Solution: At the equinoxes, the sun's altitude will be 48 degrees (90 – latitude). At summer solstice, the sun's altitude will be 71.5 degrees (48 + 23.5), and at winter solstice it will be 24.5 degrees (48 - 23.5). The shadow cast by the balcony is the sine of the sun's angle times the width of the balcony. At the winter solstice, the shadow cast will be 3.73 feet. The height of the wall space above the glass door to the bottom of the second-floor patio is a foot and a half, so 2.23 feet of the glass will be in shadow, and the remaining 4.27 feet of glass will receive sunlight. Similarly for the other angles.

High School Physics Students: Difference Between Solar Time and Clock Time and The Analemma

The time on a sundial can differ by up to as much at 16 minutes from the time on a clock. The amount of the difference depends on the time of the year, regardless of the location of the sundial. This does not mean that the time registered on the sundial is "wrong". In fact, in the 18th century a process was developed to make the pendulum clocks agree with the time given on the sundial! This process, which quantifies the difference between sun time and clock time, is called the "equation of time. " Now the standard "mean solar day" is 24 hours, but the solar day will be several seconds longer or shorter than 24 hours, depending on the time of year. Most people do not need to know the reason for this difference, but for some people with a scientific bent, an unexpected observation or data is nature's way of presenting us with a puzzle to solve. It means that there is something deeper to understand. The discussion below is for those who become fascinated when presented with a new puzzle.

A basic technique of physics is to analyze different components of motion separately and then add them together to get the observed motion. The most obvious motion is the daily path of the sun from east to west as the earth rotates. At the same time, however, the earth is revolving around the sun. With respect to the stars, the earth actually takes about 23 hours and 56 minutes to make a full turn; but since the earth is also orbiting the sun, it takes an extra four minutes to rotate a little more to see the sun in the same spot in our sky. With respect to the stars, we see the sun move about 1 degree toward the east each day. (That is, a given star will rise about 4 minutes earlier each day.) The variation in the length of the day is due to variation in this apparent eastward movement of the sun from one day to the next. The variation in length of the solar day is less than a minute per day, but over a month or two it adds up to up to 15 minutes difference between what you read on a clock and what the sundial reads.
It is easy to correct for this by using the “Equation of Time” (Here, the word “equation” is used in the sense that it equates the sundial time with the clock time.) Here is a graph of the Equation of Time.



The equation of time, is illustrated by the analemma. An analemma is the path that the sun travels in our sky over the span of a year. It is recorded through a composite photo of the sun taken at the same time each day (or once a week or once every ten days) over the course of a full year.

Have your students make a prediction: What would you expect it to look like if you record the position of the sun at exactly noon (for example) every few days during the course of a year? Many people expect it to be in a straight line along the meridian, with the lowest position in December and the highest point in June. In actuality, the result is a figure eight that is wider in the southern portion. Here is an example: https://apod.nasa.gov/apod/ap081221.html

Regardless of the location on earth, or the hour that is chosen for recording the position (as long as the sun is above the horizon at that time throughout the year), the pattern is the same: a kind of figure eight that is wider on the December – January side.

We already know that the tilt of the earth's axis causes the sun's position to appear more north during June and more south in December but the east-west shift in position unexpected. It represents a slight shift in solar time that is only perceived when we compare it to clock time. The east-west shift that causes the figure "8" shape of the analemma represents the difference between solar time and clock time.

The equation of time is the sum of two sine curves, representing two factors that influence the length of the solar day.

The first factor is the variation in the speed of the earth's orbit, described by Kepler's second law. The earth's orbit is not a perfect circle, but is slightly elliptical, with the sun at one focus. When the earth is closest to the sun (January 4), it has the highest velocity. Since it is moving faster, the sun will appear farther behind, and the earth must rotate more in order for the sun to return to the same meridian. Thus, the solar day is a bit longer in December – January, and the sundial will be slow in comparison to the clock. Conversely, when the orbit is farther from the sun in July, the velocity is a bit less, and the solar day is a bit shorter in June – July, resulting in the sundial reading ahead of clock time.

The second factor is due to the tilt of the earth's axis. It is obvious that the tilt of the axis causes the sun's position to change in the north - south direction, but it is much more difficult to understand how it causes a change in the east - west position. In order to visualize this effect, it needs to be isolated from other changes in the sun's apparent position. We can image the position of the sun changing from day to day as if the sun were revolving around the earth. Over the course of a year, the sun makes a great circle at an angle of 47 degrees to the equator (from 23.5 south to 23.5 north latitude). The sun moves along this circle at a constant speed from day to day. However, at the vernal equinox, the movement is toward the north and on the autumnal equinox the movement to toward the south. At the equinoxes, there is not an east-west component of motion. Conversely, at the solstices, there is no north-south component of motion. The sun's motion is towards the west at the summer solstice and towards the east at the winter solstice. An easterly component of motion makes the solar day a little longer, while a westerly component makes the solar day shorter.

If the earth's orbit were circular, the factor of the tilt of the axis would make an analemma in the form of a symmetrical figure 8, crossing at the equinoxes. But, given the elliptical orbit of earth, the two factors add together in the months of January and February, making the southern portion of the figure "8" longer and wider. The two factors work against each other in April and May, making the northern portion of the figure smaller and narrower.

One effect of this seasonal east – west change in the position of the sun is that everything – not just solar noon but also sunrise and sunset – are shifted slightly with respect to clock time. Although the summer solstice is the longest day of the year in the northern hemisphere, the earliest sunrise might occur a few days before and the latest sunset might occur a few days later than the solstice because of the shift in solar time *vs* clock time. At high latitudes, where the length of daylight shifts dramatically over the course of the year, this shift is not very noticeable. At the equator, where, the length of the daylight is 12 hours throughout the year, the effect of the equation of time is the only factor that makes a difference in the time of sunrise and sunset. For example, see this graph of times of sunrise, sunset, and solar noon at Quito, Ecuador: https://www.timeanddate.com/sun/ecuador/quito

Another result of this east – west change in the sun's position is that the time that the sun is at its highest position can be slightly different from the time that it crosses the meridian. Solar noon is defined as the moment that the sun crosses the meridian (when it crosses from the eastern side to the western side.) The sun may reach its highest position slightly east or west of the meridian depending upon the time of year.

All Ages: The Moon

The moon doesn't emit light, it only reflects the light from the sun. The same side of the moon is always facing the Earth. The part of the moon that is lit up is the side facing the sun. This means that we can estimate of the sun's position at night by looking at the moon and we can get an idea of the time of night by looking at the moon.

As the moon orbits around the Earth, it is sometimes on the night side of Earth, and sometimes on the daytime side. While you are observing shadows from the sun with your students, you can look for the moon, when it is visible in the day. The phases of the moon are:

- New moon is next to the sun, so we can't see it (unless there is a solar eclipse!) It rises after sunrise, and is visible in the late afternoon, following the sun towards sunset. It can be seen after sunset for a few hours, but sets before midnight. In the days after the new moon, it is in the waxing crescent phase ("waxing" means to gradually grow in size).

- First crescent phase is halfway between new moon and full moon. It rises at noon and sets at midnight. If you are out with students in the afternoon near the first crescent phase, you might look for the moon in the eastern sky. The week following first crescent is waxing gibbous phase – gibbous meaning more than half the face is lit.
- Full moon is when the moon is directly opposite the sun, so the entire face is illuminated. It rises at sunset, is in the sky all night, and sets at sunrise. The nights following the full moon is the waning gibbous phase. It is still more than half a circle, but getting smaller each night. It rises after sunset and is seen setting in the early morning.
- Last crescent is a half-moon that rises at midnight and sets at noon. Look for it towards the west during the morning. The week following last crescent is the waning crescent phase, getting thinner each day/night. It is only visible in the early morning.

As the moon orbits the Earth, the Earth must rotate a little more each day to see the moon in the same position so the moon rises a little less than an hour later each night. The moon makes a full orbit in 29.5 days, so this means that it lags behind each night by 24 (hours in a day) / 29.5 days or about 49 minutes.

The full moon is directly opposite the sun. Not only does it rise at sunset and set at sunrise, but also its path is like the sun's path at the opposite time of year. The moon's path in December is like the sun's path in June. As the South Pole tilts towards the sun in December, the north side tilts towards the night sky and the full moon. The moon is high in the sky in winter and low in summer. On a December or January night in the northern hemisphere the moon can be very bright and cast strong shadows.

This video produced by NASA shows the how the moon appears from Earth throughout the year 2022. https://apod.nasa.gov/apod/ap220201.html

All Ages: Archeoastronomy - The Study of Ancient Astronomies

Archeologists tend to spend a lot of time digging in the ground, finding potshards and ancient skeletons, and unearthing ancient buildings. It is a sophisticated science of figuring out the age of remains and uses of tools. It is rare to find an archeologist who pays attention to the heavens.

Ancient peoples often paid a great deal of attention to the movement of the sun, moon, planets, and stars. Their understanding of the celestial patterns they observed and the human place in the pattern was an essential part of their cultures. Archeoastronomy unites the fields of archeology and astronomy to better understand ancient cultures. It requires astronomers to take into account very slow changes in the orbit and tilt of the earth that are not noticeable to us in our lifetime, but which are significant when extrapolating back centuries or millennia.

To this day, the Pueblo peoples of Arizona and New Mexico designate a person to observe and record the sunrise every day from a special point. They have centuries, possibly millennia of observations of the sun. The solstices are important festivals for them, marking the change between summer activities of planting and harvesting (with the heavy "male" rains) and the winter activities (with the light "female" rains) of weaving and potting. There are several ancient markers of the equinoxes and solstices found in the Arizona – New Mexico region, in some cases estimated to be a thousand years old. One beautiful marker of the summer solstice is known as the "Sun dagger." There are two large vertical rocks with a flat rock cliff behind them. At noon, the sun shines through the gap between the two rocks and makes a dagger of light on the cliff behind. On the rock behind there is a spiral petroglyph drawn in such a way that the sun dagger reaches the center of the spiral on the summer solstice. Here is a video of the sun dagger: (from NASA's Astronomy Picture of the Day on August 5th, 2020) https://apod.nasa.gov/apod/ap200805.html

There is evidence of time-marking by ancient people in Hawai'i with the discovery of the Kānaloa stone on Kaho'olawe, the smallest island of the Hawaiian island chain(only 7 miles from Maui). The sacred rock, the Kānaloa, has petroglyphs and a row of 32 man-made depressions along one edge that align with the rising and setting of the sun. When a stick is held vertically along lines etched in the stone, the shadow of the stick aligns with man-made depressions along the edge. The island has been inhabited since the 5th century AD. Kanaloa Stone Endangered (sundials.org)

The ancient Mayans of Mesoamerica had a sophisticated calendar system based on cycles of the sun, moon, and Venus. They had an advanced mathematics that allowed for numbers in the millions (compare to Roman numerals, which are awkward!), although they did not account for the fraction of days. The solar calendar had 365 days. Without a leap year, or similar system to account for the quarter of a day each year, the dates of the solstices and equinoxes drifted one day later each four years. They venerated the "Feathered Serpent" deity. The pyramid at Chichen Itza in the Yucatan, Mexico, has an especially beautiful marker of the equinox. On the afternoon of the equinox, the shadow of the stairs makes the pattern of a serpent slithering down from the top of the pyramid. At the bottom end, the light shines on the head of the serpent carved at the base of the pyramid. Here is a video of the event: https://www.youtube.com/watch?v=Zvv9EnBuem4

This video offers additional information about Chichen Itza and the Mayan culture, including their calendar and observatory. (446) Chichén Itzá: The Great Mayan City - The Seven Wonders of the Modern World - See U in History - YouTube

Listed above are examples of ancient astronomy in the Americas, which are every bit as impressive as the famous Stonehenge in England, the Carnac Stones in France, and the sites found in ancient Greece, Rome and the middle east.

A 360° View of Stonehenge - Bing video
The Stones of Carnac: Who Built These Mysterious Ancient Megaliths? - Bing video
Sundial Discovered in Madaba Map Mosaic (sundials.org)
Hemicyclium Sundial Discovered in Turkey (sundials.org)
Antioch Mosaic Sundial (sundials.org)

These are just a few examples of ancient astronomy. It is likely that other cultures had similar markers that were less durable. Given the prevalence of archeological evidence from around the world it becomes clear that one of the first roots of science began with the human endeavor to mark time using celestial events. This 7-minute video gives a short overview of the impact of the concept of marking time on the development of human and scientific history: Ancient Astronomers - Time - Stonehenge and Sundials