Name_______________________Date___________Period __________

Seasons, Shadows, and the Path of the Sun

Lab # ____

Background

Today is the Autumnal equinox, the first day of fall in the Northern Hemisphere. What causes the seasons and what happens on each seasonal date? In this lab we will be learning the seasonal names, dates, and how the seasons change the path of the Sun for an observer in New York State. We will also investigate how the changing position of the Sun will influence the length and direction of a shadow cast by a vertical object.

Seasons are caused by 3 major factors, the tilt of the Earth's axis by 23 ½ °, the revolution of the Earth around the Sun, and the parallelism of Earth's axis. Each seasonal date is determined by when the Sun's rays hit a specific line of latitude directly, at a 90° angle. The location where the Sun's rays are striking directly is called the Vertical Ray. The Autumnal equinox happens when the Sun's Vertical Ray strikes the equator moving south. This year the Autumnal equinox happens at 10:21 Eastern Daylight Time (EDT) on September 22nd. The Fall equinox normally falls between 9/21 and 9/23. The first day of winter is called the Winter solstice. It happens when the Sun's direct ray hits the Tropic of Capricorn (23 ½° South). The Winter solstice is around December 21st (12/21). The first day of spring in the Northern Hemisphere is called the Vernal equinox. This event happens when the Sun's direct ray strikes the Equator travelling north. The Vernal equinox will happen around March 21st (3/21). The Summer solstice will normally happen around June 21st (6/21). On this day the vertical ray of the sun will strike the Tropic of Cancer (23 ½° North).

There are special observations that happen on each seasonal date. The Summer solstice is the longest daylight period of the year in New York State and the Sun will reach the highest angle at noon as well. The Winter solstice marks the fewest daylight hours with the lowest noontime altitude of the Sun. The Equinoxes, spring and fall, are the only days when we will have 12 hours of daylight and 12 hours of darkness in New York. On the Equinox the sunrise will be due East (90° azimuth) and sunset will be due West (270° azimuth). It is important for Regents Earth science students to know these specific dates and how to draw the path of the Sun for each season. We will be using a computer model in this activity to investigate how the apparent path of the Sun changes for Bellmore, NY, which is located around 41° North latitude.

Materials

Cardboard, nail, flashlight, ruler, protractor, circular protractor (360°), computer, Sun Motion Demonstrator model by the University of Nebraska Lincoln.
http://astro.unl.edu/classaction/animations/coordsmotion/sunmotions.html

Vocabulary

Autumnal Equinox	
date -	
Vernal Equinox	
date -	

Summer Solstice	
date -	
Winter Solstice	
date -	
Vertical Ray (of Sun)	
Altitude	
Azimuth	
Zenith	

Part 1 – Experimenting with Shadows and the Position of the Sun

The location of an object on the Celestial sphere can be measured using a coordinate system called altitude and azimuth. If you need a review of these terms use the Altitude/Azimuth Demonstrator from the University of Nebraska Lincoln to review and visualize this concept. http://astro.unl.edu/classaction/animations/coordsmotion/altazimuth.html

Procedure A – Altitude of the Sun (flashlight) and Length of the Shadow

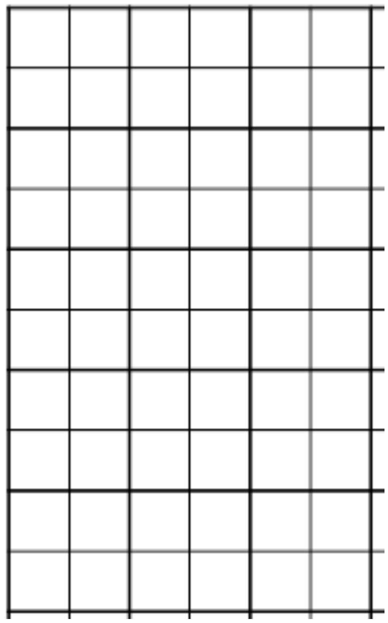
The altitude is defined as the angle above the horizon for a celestial object. If an object is located on the horizon, it will have an altitude of 0°. If the object is directly overhead, the altitude of the object will be 90°. There is an imaginary point that is directly overhead called the zenith. The zenith is at an altitude of 90° which is the maximum possible altitude for a celestial object. In this procedure we will be using a flashlight to create a shadow. The flashlight represents the Sun.

- Create a vertical post by inserting the nail through the hole in the center of your cardboard. Make sure the nail is perpendicular to your sheet of cardboard. You can secure the bottom of your nail with a small piece of electrical tape.

- Use the flashlight to cast a shadow between 1cm and 3 cm. Record the length of your shadow and the height of your name on the lines below.

  Length of Shadow ___________ cm Height of Nail ______________ cm

- On the graph paper below, create a scale model of your nail and shadow. Draw the hypotenuse of the triangle. Use your protractor to determine the altitude of your flashlight (the Sun).

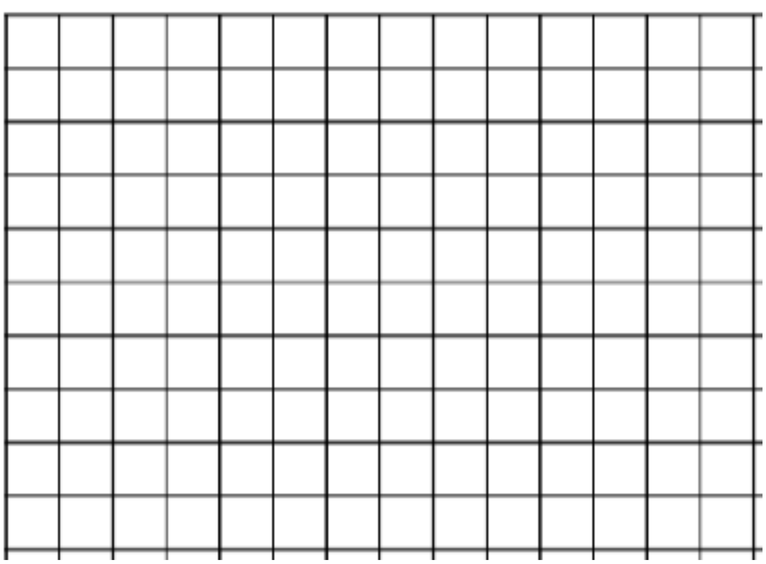


Altitude of Sun____°

Use the flashlight to create a shadow between 6 and 7 cm. Measure and record the height of the nail and the length of the shadow on the lines below.

Length of Shadow ___________ cm Height of Nail ______________ cm

- On the graph paper below, create a scale model of your nail and shadow. Draw the hypotenuse of the triangle. Use your protractor to determine the altitude of your flashlight (the Sun).



Altitude of the Sun ____ °

Questions

1. When the angle of the flashlight (Sun) was increased, what happened to the length of the shadow?

2. What type of relationship exists between the altitude of the sun and the length of the shadow?

3. The Sun reaches the highest altitude of the day at Solar noon. What must be true about the length of the shadow at solar noon on any day of the year?

4. In New York State the maximum noontime altitude of the Sun happens on the Summer solstice (6/21). What must be true about the length of the noontime shadow on this date?

5. In New York State the minimum noontime altitude of the Sun happens on the Winter solstice (12/21). What must be true about the length of the noontime shadow on this date?

Procedure B - Azimuth of the Sun (flashlight) and azimuth of the shadow

The azimuth is defined as the number of degrees clockwise from North that a celestial object is along the horizon. North has an azimuth of 0°. Azimuth has a maximum value of 360° which brings you back to North. The Four cardinal directions are 90° of azimuth from each other. East has an azimuth of exactly 90°. South has an azimuth of 180°. If a value is exactly on one of the cardinal directions the term due is placed in front of the direction. Due West would have an azimuth exactly equal to 270°. A location that is slightly off of a direction can be described by indicating which side of the direction the value is located. A location that is North of East would have an azimuth between 46° and 90° (between NE and E). A location that is South of West would have an azimuth between 225° and 270° (between SW and W).

The azimuth of the Sun appears to shift each day. Sunrise happens along the Eastern horizon and sunset is always along the Western horizon. In New York State the sun appears to move across the Southern sky. At local solar noon the sun will reach the highest altitude for the day and the Sun will be due South (azimuth of 180°). In this procedure you will be using the flashlight and the circular protractor to determine how the direction (azimuth) of the shadow is related to the direction (azimuth) of the Sun (flashlight).

Place the circular protractor so the nail protrudes through the hole located in the center of the protractor. Push the protractor down to the bottom of the nail.

Position your flashlight so it is directly shining from the East. Observe and record the direction of your flashlight (Sun) and the direction of the Shadow.

Azimuth of the Sun (flashlight) ________ ° Azimuth of the Shadow _________ °

Shift the flashlight to the South and record the information again.

Azimuth of the Sun (flashlight) ________ ° Azimuth of the Shadow _________ °

Move the flashlight to an azimuth of 225°. Record the direction of the Sun and the Azimuth of the shadow.

Direction of the Sun (flashlight) _______ Azimuth of the Shadow _________ °

Based on these observations, how is the azimuth of the Shadow related to the direction of the Sun?

If the azimuth of the shadow is less than 180°, _______ 180° to the Shadow azimuth to calculate the azimuth of the Sun.

If the azimuth of the Shadow is greater than 180°, _____________ 180° from the Shadow azimuth to calculate the azimuth of the Sun.

To simulate the apparent path of the Sun from New York State, Start with your flashlight shining from the East. Move your flashlight from East to West across the southern side of your nail.

How did your shadow appear to move as you moved the flashlight?

Part 2 – Investigating Seasonal Paths of the Sun for NY State

Models are used to represent the properties of other objects. For this part of the lab you will be using a computer model that allows you to visualize the path of the Sun for any location on the Earth's surface for any day of the year. The Sun always appears to move from East to West across the sky at a rate of 15°/hour. Focus on the location of sunrise and sunset when you run each simulation for the path of the Sun. It is also important to determine the approximate altitude of the noon Sun for each of the seasonal dates.

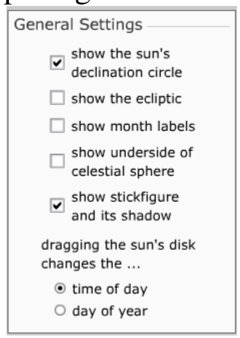
The model we will be using is found on a website created by the University of Nebraska Lincoln. There are many models on this site we will use during our investigation of astronomy. The link for the Sun Motion Demonstrator is found on the blog on our class website or at the following link, http://astro.unl.edu/classaction/animations/coordsmotion/sunmotions.html .

Procedure –

Open the model by finding the correct link. You will need to change some of the initial settings to make it easier for you to visualize what is happening.

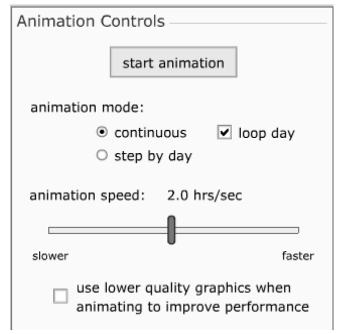
Under General Settings

- Show Sun's Declination Circle
- Show stick figure and its shadow
- Dragging the sun's disk to "time of day"



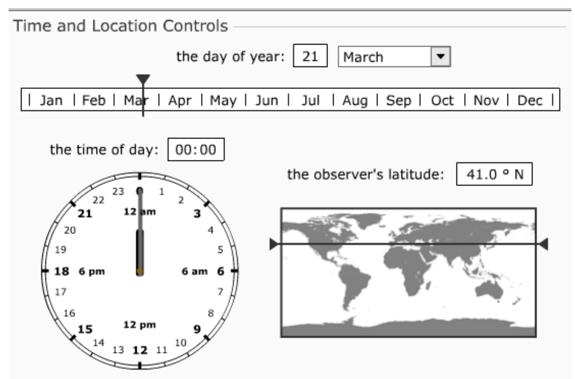
Under Animation Controls

- Click Continuous
- Click Loop Day
- Set speed to 2 hrs/sec



Time and Location Controls

- Set Latitude to 41° N
- Set Time of Day to 00:00 (Midnight)
- Set the Date to the appropriate Seasonal Date



Autumnal Equinox

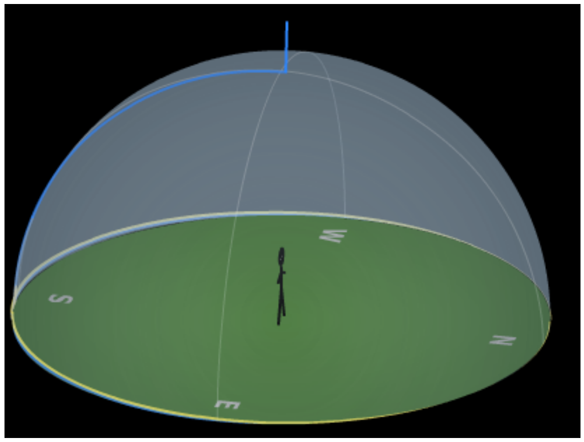
Set the Date to September 22nd. Play the animation through several times to see the path of the Sun on this seasonal date. Try to pause the Sun at the Sunrise, Sunset, and Solar noon (highest) positions. They answer the questions and draw the path on the blank Celestial sphere diagram. Label Sunrise, Sunset, and Solar noon. (If you grab the model you can rotate the diagram to view from different perspectives) You can also change the position by grabbing the Sun and dragging it along the path. You can adjust the time with the box found under Time and Location controls.

Where is the location of sunrise? (Due East, North of East, South of East)

Where is the location of sunset? (Due West, North of West, South of West)

What is the direction (azimuth) of the Sun at Solar Noon? (North, East, South, West)

Record the approximate Altitude of the Sun at Solar Noon ____________ °



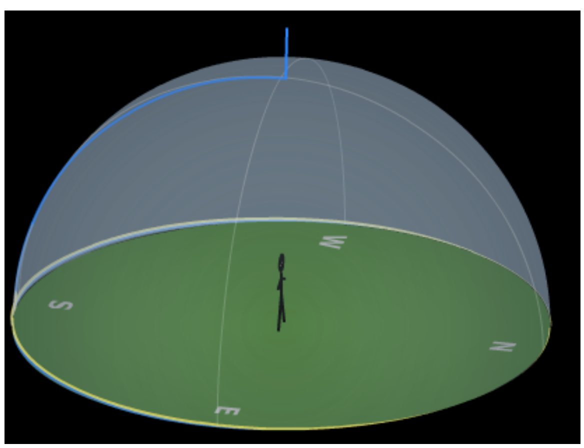
Winter Solstice
Set the Date to December 21st. Play the animation through several times to see the path of the Sun on this seasonal date. Try to pause the Sun at the Sunrise, Sunset, and Solar noon (highest) positions. They answer the questions and draw the path on the blank Celestial sphere diagram. Label Sunrise, Sunset, and Solar noon.

Where is the location of sunrise? (Due East, North of East, South of East)

Where is the location of sunset? (Due West, North of West, South of West)

What is the direction (azimuth) of the Sun at Solar Noon? (North, East, South, West)

Record the approximate Altitude of the Sun at Solar Noon ___________ °



Vernal (Spring) Equinox

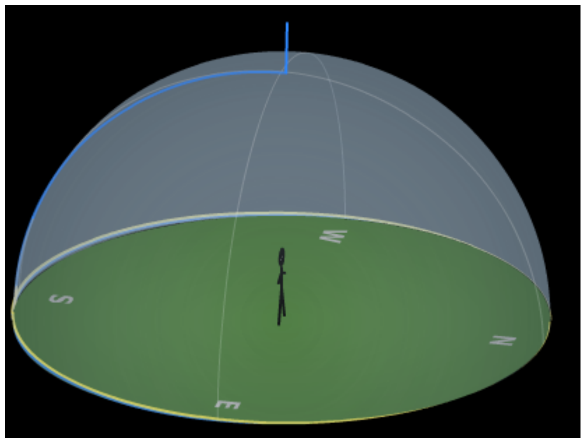
Set the Date to March 21st. Play the animation through several times to see the path of the Sun on this seasonal date. Try to pause the Sun at the Sunrise, Sunset, and Solar noon (highest) positions. They answer the questions and draw the path on the blank Celestial sphere diagram. Label Sunrise, Sunset, and Solar noon.

Where is the location of sunrise? (Due East, North of East, South of East)

Where is the location of sunset? (Due West, North of West, South of West)

What is the direction (azimuth) of the Sun at Solar Noon? (North, East, South, West)

Record the approximate Altitude of the Sun at Solar Noon ____________ °



Summer Solstice

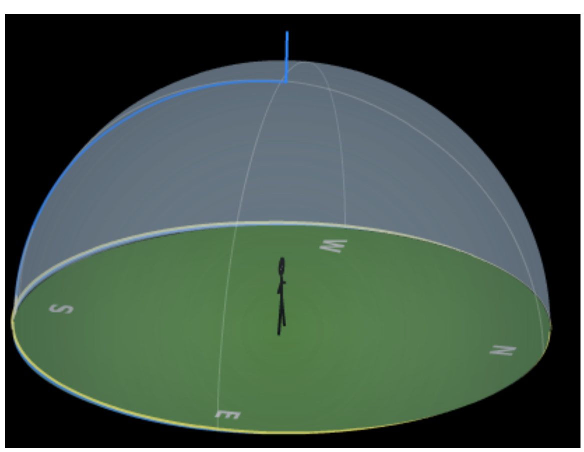
Set the Date to June 21st. Play the animation through several times to see the path of the Sun on this seasonal date. Try to pause the Sun at the Sunrise, Sunset, and Solar noon (highest) positions. They answer the questions and draw the path on the blank Celestial sphere diagram. Label Sunrise, Sunset, and Solar noon.

Where is the location of sunrise? (Due East, North of East, South of East)

Where is the location of sunset? (Due West, North of West, South of West)

What is the direction (azimuth) of the Sun at Solar Noon? (North, East, South, West)

Record the approximate Altitude of the Sun at Solar Noon ____________ °



Questions

1. List the 3 factors that cause the Earth to experience seasons.

2. If an observer moved closer to the equator, what would happen to the Altitude of the noon sun? (You could use the model to test your answer if you want.)

3. What happens to the altitude of the Sun from Sunrise till Solar noon?

4. What will happen to the length of the shadow from Sunrise until Solar noon?

5. As the Sun sets in the afternoon, what will happen to the length of the shadow?

6. If a shadow was recorded with an azimuth of 45° at a location in NYS, what is the azimuth of the Sun? What part of the day would this occur during? (Morning, Noon, Afternoon)

7. A student notices that the length of the noon shadow is getting shorter each day. Between what two seasons could this observation be made? (6 month period)

8. A student is watching the setting Sun. What direction is the student facing?

9. What direction will the noon shadow always point if you are in New York State?

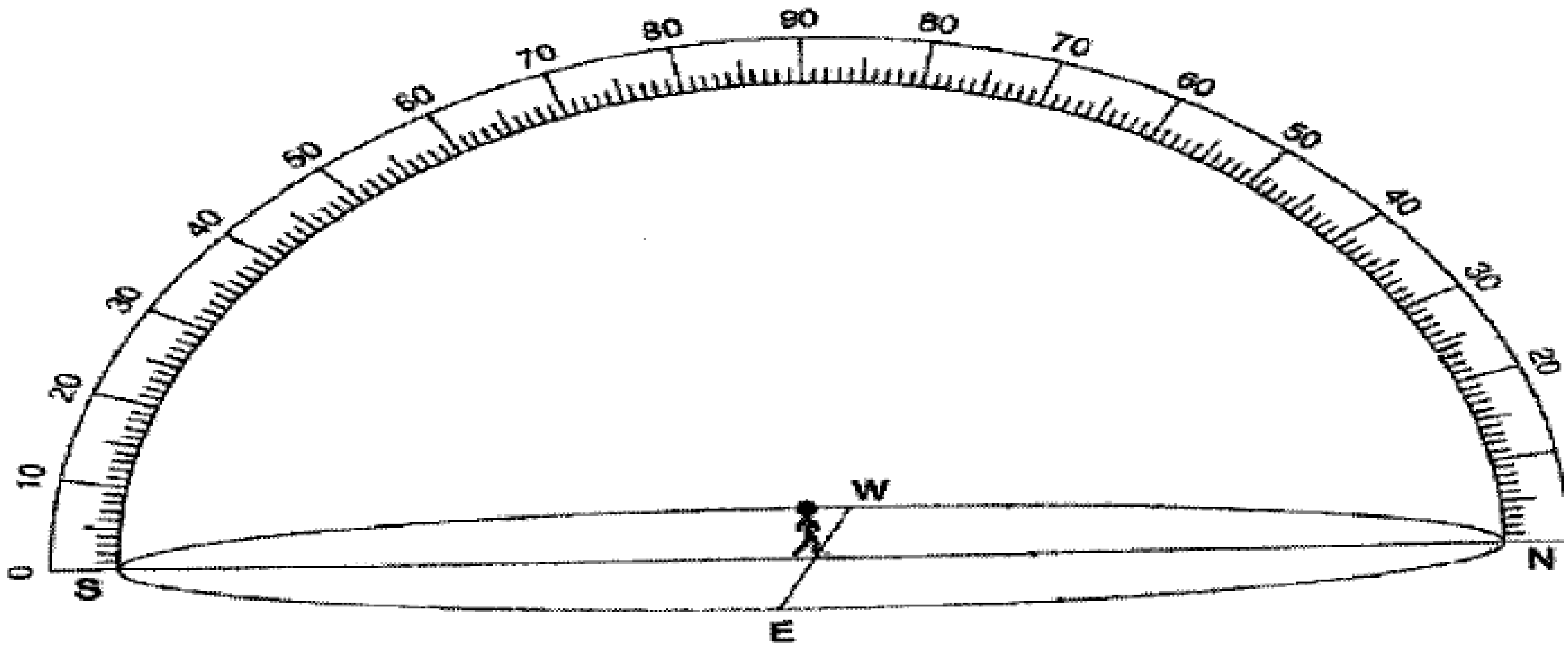
10. During what season will the Sun cast the longest shadows?

Conclusion :

As the sun appears to move across the sky from Sunrise until Sunset, describe the changes in length and direction of a shadow cast by an object in New York State. (Be sure to break this down into 2 different time intervals)

Draw the Celestial Model below

Bellmore, NY Latitude = 41°N



Draw and Highlight Equinox Path in Yellow (altitude of noon sun = 49°) Label the path EQUINOX
Draw and Highlight Summer Solstice Path in Green (altitude of noon sun = 72.5°) Label the path SUMMER SOLSTICE
Draw and Highlight Winter Solstice Path in Blue (altitude of noon sun = 25.5°) Label the path WINTER SOLSTICE