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Modeling the Apparent Path of the Sun across the Sky

Introduction

The Sun *appears* to move across our sky each day. The Sun **rises** in the **east** and **sets** in the **west**. But as you probably know by now, it only follows this *apparent* path because *the Earth itself is moving*. Since we and everything around us are on the Earth, it is the objects in the sky that seem to move. This is similar to what we think we see when we're riding in a car and objects outside, like telephone poles and the Moon) seem to whiz past us.

You also know that the **daylength** and **nightlength** change. If you are a good observer, you may also have noticed that where the Sun rises in the morning as you go to school and where it sets in the evening also vary, as does how high the Sun is in the sky, especially around noon. All of these changes are results of how the Earth **revolves** around the Sun during a year, and the **tilt** of Earth's **axis.**

These concepts can be explored through some interesting activities with a plastic hemisphere. This represents the **celestial hemisphere**—what you can see if you look from one horizon to directly above your head and down to the opposite horizon. Also by doing these activities, you should develop further your ability to understand how we can represent three-dimensional objects in two-dimensional drawings. Being able to comprehend such "spatial relationships" is an important skill in many careers.

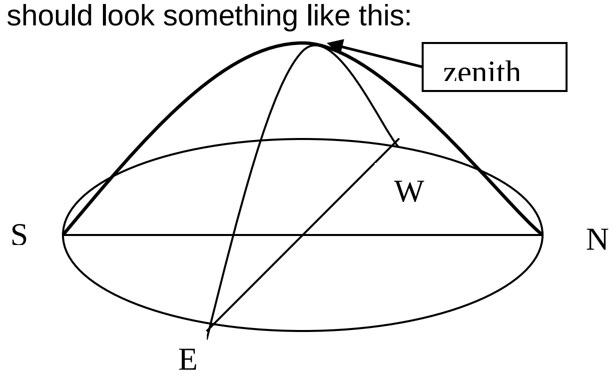
Getting Ready

You will need:

- plastic hemisphere
- paper and straight-edge
- erasable marker
- "external protractor"
- masking tape
- paper towel

1. On the paper, draw two lines intersecting in the center. Label the ends "North," "South," "East," and "West."
2. Place the plastic hemisphere on the table with its highest point (**zenith**) above the center intersection. Use the marker to indicate "North," "South," "East," and "West" at the edges.
3. Take a piece of masking tape and attach it from the zenith to the "South" mark. This represents a **meridian** (imaginary line from the North Pole through any location to the South Pole.)

Your hemisphere should look something like this:



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Activities

1. What is the path of the Sun here in Englewood at the time of the **equinoxes**?

You know that the Sun is directly over the Equator twice a year at the **spring** (**vernal**) **equinox** and the fall (**autumnal**) **equinox**. On these days, the Sun rises exactly east and sets exactly west. In this activity, you will learn how to make a model of the Sun's path on those dates across the sky here in Englewood.

The key to this is determining how high above the southern horizon the Sun will be at local noon. It turns out this is very easy to do if you know your latitude. Englewood is at **latitude 40$^o$ N**. So if the Sun is directly overhead (90$^o$) at the Equator (0$^o$), then it will be 90$^o$ - 40$^o$ = 50$^o$ above the horizon when it crosses the meridian (in your model, the zenith-to-south line.)

Use the external protractor to mark 50$^o$ up from the bottom edge on your zenith-to-south masking tape. Then take another piece of masking tape and place it from the "East" mark over your 50$^o$ mark to the "West" mark. Draw the zenith-to-south line on the masking tape. (Try to make this thin.) Label this line "12 Noon."

2. Where would the Sun be at a given hour of the day?

At **solar noon** (which may not be clock noon), the Sun will be exactly south of an observer in NJ. But where will it be at other times of the day? You know that the Earth **rotates** 360$^o$ in 24 hours, so how many degrees does it turn in 1 hour? That's simple:

$$360^o / 24 \text{ hours} = 15^o \text{ per hour}$$

Use your external protractor to mark off on the masking tape every 15$^o$ on both sides of your 12 noon mark. Label these times on the tape. If you have done all the steps correctly so far, you should find that at the time of the equinoxes, the Sun is in the sky for about 12 hours. It rises about 6 a.m. and sets about 6 p.m. If you did not find these, try to explain possible errors:

3. What is the path of the Sun here in Englewood at the time of the **solstices**?

At the Summer Solstice, the Sun at solar noon is directly overhead at the **Tropic of Cancer** (**23-1/2$^o$ N**.) Since Englewood is at 40$^o$, this means that the Sun would be 40$^o$ – 23.5$^o$ = 16.5$^o$ away from overhead, or 90$^o$ – 16.5$^o$ = 73.5$^o$ above the southern horizon on the meridian.

Use your external protractor to make this mark on the zenith-to-south meridian tape line.

Since the Sun is north of the Equator, the position at which the Sun rises will also shift to a location north of due east. At the summer equinox, this will be $23.5^o$ north of your "East" mark. Similarly, the Sun will set $23.5^o$ north of your "West" mark.

Use the external protractor to identify these positions. Then use masking tape to represent the path of the Sun across the sky at the time of the summer solstice. Next, mark off the hours, as you did for the time of the equinoxes.

Compared with the equinoxes, is daylength longer? Circle: Yes No

By how many hours, approximately? ___________

Does this agree with what you learned in an earlier activity? Explain.

At the Winter Solstice, the Sun is directly overhead at the **Tropic of Capricorn** (**23-1/2$^o$ S**.) This latitude is $40^o$ + 23-1/2$^o$ = 63-1/2$^o$ away from us, so at solar noon the Sun would only be $90^o - 63.5^o = 26.5^o$ above the horizon.

As before:

--Mark this on your zenith-to-south meridian line

--Identify the locations where the Sun would rise ($26.5^o$ south of East) and set ($26.5^o$ south of West).

--Use masking tape to represent the path of the Sun across the sky at the time of the winter solstice.

--Mark off the hours, as you did for the time of the equinoxes and summer solstice.

Compared with the equinoxes, is daylength longer? Circle: Yes No

By how many hours, approximately? ___________

Does this agree with what you learned in an earlier activity? Explain.

4. Comparing 3-D and 2-D models

Your textbook and images on computers are two-dimensional (2-D), but the real situation and your physical model are three-dimensional. The drawing on the first page shows the **perspective** (point of view) as if you are looking from above the northeast. Turn your model so it has the same perspective as the drawing. Do you see the similarities?

On the next page, try to draw your model as you look at it:

(A) from directly to the south (looking north)

(B) from the southeast view

(C) from the southwest view

5. Using the Internet to Learn More

Go online to view these links and, on another piece of paper, tell at least two things you learned from each. (Be sure to identify which link you are discussing.)

Position of the Sun on the horizon at sunrise
http://astro.unl.edu/classaction/animations/coordsmotion/horizon.html

Calculating the **altitude** (angle above the horizon) and **azimuth** (compass direction)
http://aa.usno.navy.mil/data/docs/AltAz.php

Ask an Astronomer: Why Does the Location of Sunrise Change?
http://curious.astro.cornell.edu/question.php?number=498

Extra credit: Find another useful website and let me know about it.

6. Cleaning Up

When you are finished:

1. Take off the masking tapes and place them on another piece of paper that you attach to this lab report. Label each.

2. Put the clean hemisphere, masking tape, external protractor, etc., back into the box.

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(A) from directly to the south (looking north)

(B) from the southeast view

(C) from the southwest view

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Extension Activities and Question

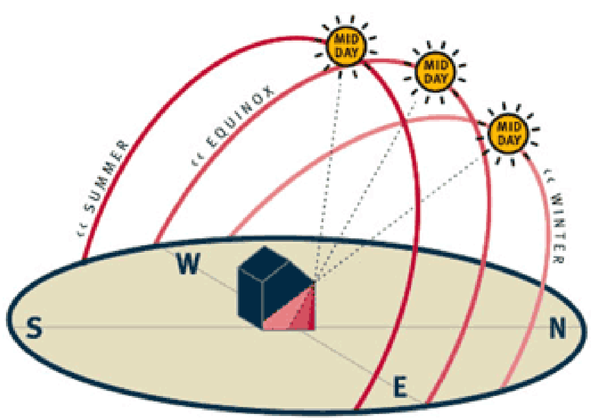
Answer these on additional sheets attached to these.

1. The "figure-8" (analemma) markings on some globes indicate the approximate latitude at which the Sun is overhead on any day. Use this and the examples above to calculate the approximate angle of the Sun at solar noon for today. Show your work.

2. Try to figure out what the Sun's path would be for an observer at the Equator at the time of the equinoxes and solstices, using your plastic hemisphere. This should help explain why there are always twelve hours of day and twelve hours of night at the equator. Explain what you did and provide a drawing.

3. Use the plastic hemisphere to try to make a model of the Sun's path at the North Pole at the time of the equinoxes and summer solstice. This should help explain why the Poles have six months of "day" and six months of "night." Explain what you did and provide a drawing.

4. Explain how your model would be different if the observer were at 40 $^{o}$ S? Hint: Look at the diagram below and notice its url. (Use additional paper, if necessary.)




http://www.works.qld.gov.au/