Physics 115 Name(s): \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

UW–Eau Claire

**Solar Motion Simulator Activity**

# Learning Objectives

How we see the Sun moving in the sky depends on our viewing geometry: where we are on Earth *and* how Earth is oriented with respect to the Sun. The Solar Motion Simulator allows us to model the viewing geometry and understand how the Sun’s daily motions change depending on the observer’s latitude and time of year.

**We will focus on the following objectives:**

1. Describe the path of the Sun in the sky on a daily basis.
2. Describe how the elevation of the Sun at noon changes depending on the season and latitude.
3. Understand how sunrise/sunset times (and consequently, the amount of daylight) vary throughout the year.
4. Determine how sunrise/sunset locations vary throughout the year.

# Part 1: Introduction

The observer’s position is fixed at the center point on the Horizon Disk, and the edge of the disk represents their horizon. From that vantage point, they can watch the “Sun” as it moves in an arcing path above them.

But where will the Sun be in the sky at a given point in time? You can use the Solar Motion Simulator to determine (approximately!) where the observer would see the Sun according to the following three settings:

* **Observer’s Latitude**: The observer’s latitude helps determines how their horizon is oriented with respect to the Sun on Earth’s curved surface. Swivel the Horizon Disk so that the southern tip of the disk lines up with the desired latitude.
* **Time of Day:** As Earth spins on its axis each day, the observer will see the Sun appear to move from one side of the horizon to the other. Swivel the Solar Arm so that the “Time of day” indicator at its base points to the desired time on the Time Dial.
* **Solar Declination (time of year):** Earth’s tilt causes the Earth to oscillate between tilting towards or away from the Sun, depending on the time of year. Simulate the time of year by moving your “Sun” along the Solar Arm. The dates corresponding to different solar declinations are listed lower on the Solar Arm.

Take a few minutes to become familiar with the different parts of the Solar Motion Simulator.

# Part 2: (Tutorial) The Sun’s Apparent Daily Path

**Objective: Learn how to use the Solar Motion Simulator.**

## Experiment

Simulate the path of the Sun on the spring equinox (March 20ish) for an observer at 45ºN:

1. Observer’s Latitude: Swivel the Horizon Disk so that the southern tip of the disk lines up with an observer’s latitude of 45º N.
2. Solar Declination (time of year): Move the box on the Solar Arm (representing the Sun) to a solar declination of 0º for the spring equinox.
3. Time of Day: (we’ll simulate one full day)
   1. Start with the Solar Arm rotated so that the “Sun” is just after midnight (say, 1 AM) as indicated by the “Time of day” marking on the bottom of the Solar Arm. Note that our Sun is *below* the horizon, so it’s night time for our observer.
   2. Slowly swivel the Solar Arm forward in time until the Sun crosses the plane of the Horizon Disk. Sunrise is when the Sun moves from *below* the horizon to *above* it. In this specific case, sunrise should happen at 6 AM when the Sun is at an azimuth of 90º (due east) on the observer’s horizon.
   3. Rotate the Solar Arm so that the time is 12 (noon). The Sun should have risen far above the Horizon Disk. At this point, it is at its highest point in its daily path. Note that because the Sun is above the Horizon, it’s *day*.
   4. Fast-forward time by moving the Solar Arm to when the Sun crosses the observer’s horizon again. This time, since it’s moving from *above* the horizon to *below* it, we call it *sunset*. This should happen at a time of 18 (6 PM).
   5. Fast forward time to just before midnight (say, 23 or 11 PM). The Sun is now almost as far below the observer’s horizon as it will get: it’s approaching midnight.

## Questions

1. In this scenario, would the observer say that the Sun moved east-to-west or west-to-east across the sky? Circle one:

EAST 🡪WEST WEST 🡪 EAST

1. Will the Sun *always* move in the same sense (east-to-west vs. west-to-east) for observers at *all* latitudes? If so, explain why. If not, what does it depend on?
2. In this model, will the Sun *always* be the highest in the sky at 12 (noon)? Justify your answer.

# Part 3: The Sun’s Elevation Angle at Noon

**Objective: Describe how the Sun’s elevation at noon varies at different latitudes.**

## Experiment

Put the Solar Arm in the noon position. Move the solar declination to 0º (corresponding to either equinox). Adjust the observer’s latitude and fill in the table below.

|  |  |
| --- | --- |
| Observer’s Location | Angle of Sun Above Horizon |
| North Pole (90ºN) |  |
| New York City, USA (41ºN) |  |
| Quito, Ecuador (0º) |  |
| Sydney, Australia (34ºS) |  |
| South Pole (90ºS) |  |

## Questions

1. Is the noon Sun located in the northern or southern sky for an observer in Sydney?
2. Is the noon Sun *always* located due south for somebody in New York City? How do you know?
3. How does the location of the noon Sun change as you move further north of the equator?
4. At what latitude is the noon Sun directly overhead on an equinox?
5. At which latitude(s) will the noon Sun be on the horizon on March 21?

# Part 3: Seasonal Dependence of the Sun’s Elevation Angle at Noon

**Objective: Describe how the Sun’s elevation at noon varies throughout the year.**

As Earth orbits the Sun, its rotation axis stays in the same direction in space, causing Earth to lean *toward* the Sun on one side of its orbit (a solstice), lean *away* from the Sun on the opposite side of its orbit (another solstice), and lean *neither toward nor away* from it at the two intermediate points (called equinoxes) in between solstices. This causes the elevation of the Sun in the sky to change on a seasonal basis. In the Solar Motion Simulator, you can change the time of year by sliding the Sun to a different solar declination. Approximate dates for the solstices and equinoxes, along with the corresponding solar declination values, are given near the bottom of the Solar Arm.

## Prediction

1. Based on your experience, does the height of the Sun change seasonally? If so, how?

## Experiment

Choose a location and use fill out the table below. Look up the local season if unsure.

**Location:** \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ **Location’s** **Latitude:** \_\_\_\_\_\_\_\_\_\_\_

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Solar Declination | Approximate Dates | Season | Angle of Noon Sun above horizon | Is Sun due north, due south, or overhead? |
| –23.5º (southern solstice) | Dec. 20–22 |  |  |  |
| 0º (northward equinox) | Mar. 19–21 |  |  |  |
| +23.5º (northern solstice) | Jun. 20–21 |  |  |  |
| 0º (southward equinox) | Sep. 21–24 |  |  |  |

## Questions

1. Is the Sun higher in the sky in New York City (41ºN) or Sydney (34ºS) on December 21? Why?

1. Describe how the location of the noon Sun changes throughout the year for somebody in New York City (41ºN).
2. Describe how the location of the noon Sun changes throughout the year for somebody at the equator.

# Part 4: Sunrise/Sunset Times, Location and Length of Day

**Objectives: Describe how sunrises/sunsets vary seasonally.**

Estimate the sunrise and sunset times for your location from earlier. Also, estimate the location (azimuth, or compass direction on the observer’s horizon) of sunrise and sunset. Finally, use the sunrise and sunset times to estimate the number of hours of daylight for your location.

## Prediction

1. Based on your experience, is the amount of daylight related to season? If so, how?
2. Based on your experience, does the Sun always rise and set in the same locations each day throughout the year?

## Experiment

Choose a location and use fill out the table below. Look up the local season if unsure.

**Location:** \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ **Location’s** **Latitude:** \_\_\_\_\_\_\_\_\_\_\_

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Approximate Dates | Season | Sunrise | | Sunset | | Hours of Daylight |
| Location | Time | Location | Time |
| Dec. 20–22 |  |  |  |  |  |  |
| Mar. 19–21 |  |  |  |  |  |  |
| Jun. 20–21 |  |  |  |  |  |  |
| Sep. 21–24 |  |  |  |  |  |  |

## Questions

1. Does the amount of daylight depend on season? If so, how?
2. Does the location of sunrise/sunset change seasonally? If so, how?
3. Do you think these results would be different for an observer on the opposite side of Earth? Use your Solar Motion Simulator to test your prediction. Were you right?

# Digging Deeper

Choose one of the following questions to investigate. Use the Solar Motion Simulator to explain your answer.

1. What are two different ways that the Sun’s path in the sky drives the seasons?
2. Will sunrise/sunset always be the same amount of time away from when the Sun crosses the meridian?
3. Is it possible for some locations to experience a full 24 hours of sunlight? When and where?
4. If the Sun’s path is perpendicular to the horizon, sunrise/sunset will happen faster. Where is the sunrise/sunset fastest on an equinox? How about for each solstice?
5. Are there any dates for which the sunrise and sunset times do not depend on latitude? (Hint: there are exactly two such dates.)
6. Does the equator have a “winter”? If so, where is the Sun in the sky? If not, why not?
7. On what dates are there are equal amounts of nighttime and daytime? (Hint: there are exactly two.)
8. Does it take the Sun the same amount of time to go from sunrise to noon as it does to go from noon to sunset? If so, does the Solar Motion Simulator reflect this? If not, what might be the cause?
9. (Challenge) Look up the *actual* sunrise/sunset and solar noon times for today at your current location. Compare them to the times predicted by the Solar Motion Simulator for today’s date at your location. What might be causing them to be different? For a hint, see <http://blog.poormansmath.net/how-much-is-time-wrong-around-the-world/>.

**Your Question:** #\_\_\_\_\_

**Your Answer:**

## If time permits…

Find somebody who chose a different question than you did. Ask them your question and see if they can answer it using the Solar Motion Simulator!