Learning Critical Thinking Through Astronomy: Sun's Daily And Annual Motions

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STUDENT NOTE

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Contents

Questions

Why do we see different constellations at different times of night? Why do we see different constellations at different times of year?

Materials Needed

For this activity, you will need the following materials:

- your model celestial sphere, already constructed
- a pencil (do not use ink)
- the ability to read and follow directions

Points To Remember

Don't attempt to draw any inferences unless you are asked to do so. Don't confuse a simple description of an observation, the explanation of that observation, and what can be learned from that observation. You cannot draw inferences until you have assembled a sufficient number of accurate observations. You'll recognize when you're expected to draw inferences.

The same advice about terminology in previous shadow activities applies in this activity as well.

1 Celestial Reference Markers

Before beginning this activity, you must have already constructed a model celestial sphere. Constructing the celestial sphere is a time consuming activity in itself and is not part of this activity and is not described here.

Your instructor should introduce the following **reference markers** on your celestial sphere:

- north-south line
- celestial meridian
- east-west line
- prime vertical
- horizon
- celestial poles
- zenith
- celestial equator
- ecliptic
- equinox

- solstice
- time bumps (a weird name, but it fits)

STUDENT NOTE

Despite their inclusion in this list, **DO NOT** treat time bumps as celestial reference markers in any subsequent questions.

You **must** thoroughly understand the concepts behind these reference markers and be able to identify and operationally define them at any time. Take some time **now** to identify each one **yourself and with a colleague** before going any further in this activity.

STUDENT NOTE

Add these terms to your glossary.

Finally, you must understand that there are two ways, and only two ways, things can "move" in your model. **The first is Sun can move along the ecliptic.** By definition, Sun can **only** move along the ecliptic. **The second is the entire sky can be moved around Earth by twisting the entire sphere around the stick. Earth does not move in any way in this model.** Read that last sentence at least three more times. All explanations based on this model must not in any way resort to Earth "moving." Nevermind what you think you may already know.

STUDENT NOTE

It is very important that you **not** appeal to Earth moving in any way for this activity. Any response on this activity or on any subsequent assessment that appeals to a moving Earth is considered incorrect.

|——— CHECKPOINT ———|

2 Settings

2.1 Setting A Particular Date

Once you understand the concept behind Sun's annual path around the sky, you are ready to set your celestial sphere for any particular date within the year. All you have to do is physically move the pin representing Sun to the desired date along Sun's annual path around the sky. To fully understand this concept, it is important that you actually move the pin and not just imagine moving the pin.

STUDENT NOTE

Specifying a particular date is equivalent to specifying Sun's position along the ecliptic.

STUDENT NOTE

For this activity, make sure your celestial sphere is set for Hickory.

2.2 Setting A Particular Time

Once you have set the date, you can further specify a particular time of day. You know from previous activities that a stick's shadow's length is minimum at noon. You know that this implies Sun is at its highest point above the horizon at noon. Given what you now know about your celestial sphere, this implies Sun must be somewhere on the celestial meridian at noon. It is essential that you convince yourself of this before going any further in this activity. You should now figure out how to set your celestial sphere for sunrise and sunset.

STUDENT NOTE

Specifying a particular time is equivalent to specifying Sun's position relative to the celestial meridian.

2.3 Initializing Your Sphere

To properly initialize your celestial sphere, place the sphere into the box so that the stick makes an arbitrary angle with respect to the vertical. The value of the angle is not critical, but the stick should be neither vertical nor horizontal. There is no need to make your setup look identical to anyone else's. Adjust the sphere on the stick so that half the sphere is above the paper horizon and half is below. You may need to use tape to keep the sphere from sliding down the stick. The entire sphere-stick-block assembly should be rotated in the box so that the stick's tip is directly over the word "North" on the paper horizon.

STUDENT NOTE

The celestial sphere must be properly initialized before every use. Otherwise, it will not give a reliable simulation of Nature.

|——— CHECKPOINT ———|

3 Shadows Redux

3.1 Day Of March Equinox

1. Set your celestial sphere for the date on which Sun is at the March equinox. You have to physically move the pin representing Sun to the location on the ecliptic for that specific date. What three celestial reference markers is Sun on for this date?

STUDENT NOTE

Remember that time bumps are not true celestial reference markers, so do not name them. There should be nothing otherwise tricky about this question.

Response

2. **Set the time to sunrise for this date.** This means you must adjust the sphere so that Sun is right on the horizon somewhere in the eastern half of the sky. Consider an imaginary observer on Earth's surface directly below the zenith. What direction must this observer face to see Sun rising on this date?

STUDENT NOTE

Do not rely on old sayings like "Sun always rises in the east" to answer this question. Rely on the science resources you have, namely your properly constructed and adjusted celestial sphere and your ability to reason even in the presence of cognitive dissonance. If you still think that old saying is true, then you need to revisit, and actually do, the shadow activities.

STUDENT NOTE

Use **ONLY** the direction names you were permitted to use in the shadow activities. **DO NOT** use northeast, northwest, southeast, or southwest at all for any reason.

Response

3. In what direction would the sunrise shadow of a stick at the observer's location point on this date?

STUDENT NOTE

Use **ONLY** the direction names you were permitted to use in the shadow activities. **DO NOT** use northeast, northwest, southeast, or southwest at all for any reason.

STUDENT NOTE

There should be nothing tricky about this question.

Response

4. **Set the time to noon for this date.** What celestial reference marker is Sun **always** on at noon, and **only** at noon, regardless of the observer's location on Earth?

STUDENT NOTE

Remember that time bumps are not true celestial reference markers, so do not name them. There should be nothing otherwise tricky about this question.

Response

5. Where is Sun relative to the zenith? There are only three possible choices. One is that Sun is at the zenith, one is that Sun is north of the zenith, and one is that Sun is south of the zenith. Choose which one is appropriate for your situation.

Response

6. Based on your response to the previous question, in what direction will a stick's noon shadow point on this date?

STUDENT NOTE

Use **ONLY** the direction names you were permitted to use in the shadow activities. **DO NOT** use northeast, northwest, southeast, or southwest at all for any reason.

Response

7. **Set the time to sunset for this date.** What direction must the observer face to see Sun setting on this date?

STUDENT NOTE

Do not rely on old sayings like "Sun always rises in the east" to answer this question. Rely on the science resources you have, namely your properly constructed and adjusted celestial sphere and your ability to reason even in the presence of cognitive dissonance. If you think that old saying is true, then you need to revisit, and actually do, the shadow activities.

STUDENT NOTE

Use **ONLY** the direction names you were permitted to use in the shadow activities. **DO NOT** use northeast, northwest, southeast, or southwest at all for any reason.

Response

8. In what direction would the sunset shadow of a stick at the observer's location point on this date?

STUDENT NOTE

Use **ONLY** the direction names you were permitted to use in the shadow activities. **DO NOT** use northeast, northwest, southeast, or southwest at all for any reason.

STUDENT NOTE

There should be nothing tricky about this question.

Response

3.2 Day Of June Solstice

9. Set your celestial sphere for the date on which Sun is at the June solstice. You have to physically move the pin representing Sun to the location on the ecliptic for that specific date. What celestial reference marker(s) is(are) Sun on for this date?

STUDENT NOTE

All of the Student Notes in the previous section apply to this and all subsequent sections and questions therein.

Response

10. **Set the time to sunrise for this date.** This means you must adjust the sphere so that Sun is right on the horizon somewhere in the eastern half of the sky. Consider an imaginary observer on Earth's surface in the center of the celestial sphere. What direction must this observer face to see Sun rising on this date?

Response

11. In what direction would the sunrise shadow of a stick at the observer's location point on this date?

Response

12. **Set the time to noon for this date.** What celestial reference marker is Sun always on at noon, and **only** at noon, for any location?

Response

13. Where is Sun relative to the zenith? There are only three possible choices. One is that Sun is at the zenith, one is that Sun is north of the zenith, and one is that Sun is south of the zenith. Choose which one is appropriate for your situation.

Response

14. Based on your response to the previous question, in what direction will a stick's noon shadow point on this date?

Response

15. **Set the time to sunset for this date.** What direction must the observer face to see Sun setting on this date?

Response

16. In what direction would the sunset shadow of a stick at the observer's location point on this date?

Response

3.3 Day Of September Equinox

Set your celestial sphere for the date on which Sun is at the September equinox. Work through the same questions as in the previous section.

3.4 Day of December Solstice

Set your celestial sphere for the date on which Sun is at the December solstice. Work through the same questions as in the previous section.

STUDENT NOTE

At this point, you must be certain that you have correctly replicated your previously recorded shadow observations. Do not go any further in this activity unless you have done so.

|——— CHECKPOINT ———|

4 Explaining

4.1 Direction Of Sunrise Shadows

17. Consider the *direction* of a stick's sunrise shadow. You have observed that it changes during the year. Make a list of **at least three** factors that could play a role in explaining this behavior. State each factor as a complete sentence.

STUDENT NOTE

As an example, you might write this: The stick's height changes throughout the year.

STUDENT NOTE

Each factor you come up with must be something you can isolate from all other factors and test to see whether or not it affects a sunrise shadow's direction. When you're dealing with Sun's motion around the sky, the ecliptic is always important. You know that during the year, Sun's position along the ecliptic changes and that is certainly something you can isolate. Maybe you should list that.

When you talk about sunrise or sunset, you must consider the horizon. Using your sphere, you should be able to see that at sunrise on any given date, the point along the horizon where the ecliptic intersects the horizon changes during the year. This effect can probably be isolated. Maybe you should list that.

Geometry is important in understanding the properties of the celestial sphere. Look at the ecliptic and the celestial equator. Note that they do not coincide. What if they did? Does the fact that they do not coincide affect the sunrise shadow's direction? This effect can probably be isolated. Maybe you should list that.

Response

18. For **each** of the factors you listed above, perform a test with your celestial sphere to determine its effect on the direction of a stick's sunrise shadow. You do this by **varying** the factor you're testing **while holding all the other factors constant**. The idea is to isolate one factor at a time to see what effect, if any, it has on what you're investigating. The following table has room for six factors that may play a role in explaining the sunrise shadow's behavior even though you may have considered fewer than six factors. One example is shown.

Factor To Isolate	**Observed Effect**
stick's height	no effect on sunrise shadow's behavior

If none of the factors you isolated produced any observable effect on the sunrise shadow's behavior, you need to go back and look for factors that do indeed produce observable effects.

Finally, combine the factors that produced observable effects into a single complete sentence that explains why a stick's sunrise shadow's direction varies during the year. This may be a rather long sentence!

Response

4.2 Direction Of Sunset Shadows

19. Consider the *direction* of a stick's sunset shadow. Repeat the entirety of the previous question for a stick's sunset shadow.

Factor To Isolate	**Observed Effect**
stick's height	no effect on sunset shadow's behavior

If none of the factors you isolated produced any observable effect on the sunset shadow's behavior, you need to go back and look for factors that do indeed produce observable effects.

Finally, combine the factors that produced observable effects into a single complete sentence that explains why a stick's sunset shadow's direction varies during the year. This may be a rather long sentence!

Response

4.3 Direction Of Noon Shadows

20. Consider the *direction* of a stick's noon shadow. Repeat the entirety of the previous question for a stick's sunset shadow.

Factor To Isolate	Observed Effect
stick's height	no effect on noon shadow's behavior

If none of the factors you isolated produced any observable effect on the noon shadow's behavior, you need to go back and look for factors that do indeed produce observable effects.

Finally, combine the factors that produced observable effects into a single complete sentence that explains why a stick's noon shadow's direction behaves as it does during the year. This may be a rather long sentence!

Response

5 Inquiry

5.1 Simulating Constellation Visibility

Modern astronomers think of *constellations* on the sky much like geographers think of *states* on a map of America. That is, they are merely bordered regions that help us roughly locate celestial object. In antiquity, constellations were thought of as recognizable patterns among the stars; we would call them *stick figures* today. The division of the sky into the eighty-eight modern constellations is of no real scientific value, but the constellations along the ecliptic provide a convenient background against which we can see Sun's annual motion.

STUDENT NOTE

There is absolutely **no astronomical significance** to constellations other than as a very crude way to specify an object's location on the sky. Most astronomers do not use constellation names in their scientific work, and locate objects using a coordinate grid similar to the latitude and longitude grid we use for locating cities on a map of Earth's surface.

21. Pick eight dates evenly spaced through the year. You may include the four dates from the previous part of this activity or you may choose your own. For each date, set your sphere to **midnight** and observe which constellation along the ecliptic is closest to the celestial meridian. When you change dates, describe the location, relative to the celestial meridian, of the constellation that was nearest the celestial meridian on the previous date. Fill in the following table with your simulated observations.

Date	Constellation Nearest Celestial Meridian	Location Of Previous Constellation On This Date
		N/A

22. Why do we see different constellation at different times of night?

Response

23. Why do we see different constellations at different times of year?

Response

24. What was(were) the purpose(s) of this activity?

Response

|——— CHECKPOINT ———|

25. Map this activity into as many of the elements of thought as you can.

Response

26. Every activity will have at least one standard associated with it.

> **STANDARD**
>
> I can identify, model, and explain patterns related to a shadow's behavior, Sun's apparent motions, and constellation visibility using my celestial sphere.

6 Feedback

What could be done to make this activity more interesting? Please be honest.

Response