

## 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:

- a 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 Setting Your Celestial Sphere

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)

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.

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.

### — CHECKPOINT —

## 1.1 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.

**IMPORTANT CONCEPT: Specifying a particular date is equivalent to specifying Sun’s position along the ecliptic.**

## 1.2 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.

**IMPORTANT CONCEPT: Specifying a particular time is equivalent to specifying Sun’s position relative to the celestial meridian.**

## 1.3 Initializing Your Sphere

To properly initialize your celestial sphere, place the stick into the styrofoam block at 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. Now place the entire assembly down into the cardboard box and 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.

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

———— CHECKPOINT ————

## 2 Shadows Redux

### 2.1 March Equinox

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 two celestial reference markers is Sun on for this date?

Now 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?

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

Set the time to sunset for this date.

What direction must the observer face to see Sun setting on this date?

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

Finally, set the time to noon for this date.

What celestial reference marker is Sun on at noon?

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.

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

## 2.2 June Solstice

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 is Sun on for this date?

Now 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?

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

Set the time to sunset for this date.

What direction must the observer face to see Sun setting on this date?

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

Finally, set the time to noon for this date.

What celestial reference marker is Sun on at noon?

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.

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

### 2.3 September Equinox

Set your celestial sphere for the date on which Sun is at the September equinox. You have to physically move the pin representing Sun to the location on the ecliptic for that specific date.

What two celestial reference markers is Sun on for this date?

Now 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?

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

Set the time to sunset for this date.

What direction must the observer face to see Sun setting on this date?

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

Finally, set the time to noon for this date.

What celestial reference marker is Sun on at noon?

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.

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

## 2.4 December Solstice

Set your celestial sphere for the date on which Sun is at the December solstice. You have to physically move the pin representing Sun to the location on the ecliptic for that specific date.

What celestial reference marker is Sun on for this date?

Now 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?

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

Set the time to sunset for this date.

What direction must the observer face to see Sun setting on this date?

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

Finally, set the time to noon for this date.

What celestial reference marker is Sun on at noon?

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.

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

**IMPORTANT: 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.**

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### 3 Explaining Shadows With Science

#### 3.1 Direction Of Sunrise Shadows

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. (Example: Sun's position relative to the horizon changes.)

For **each** of the factors you listed above, perform a simulation 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!

### 3.2 Direction Of Sunset Shadows

Consider the *direction* of a stick's sunset 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. (Example: Sun's position relative to the horizon changes.)

For **each** of the factors you listed above, perform a simulation with your celestial sphere to determine its effect on the direction of a stick's sunset 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 sunset 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 sunset shadow's direction varies during the year. This may be a rather long sentence!

### 3.3 Direction Of Noon Shadows

Consider the *direction* of a stick's noon shadow. You have observed that sometimes it changes during the year and sometimes it does not. Make a list of **at least three** factors that could play a role in explaining this behavior. State each factor as a complete sentence. (Example: Sun's position relative to the horizon changes.)

For **each** of the factors you listed above, perform a simulation with your celestial sphere to determine its effect on the direction of a stick's sunset 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 noon 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 noon shadow's direction sometimes varies during the year. This may be a rather long sentence!

## 4 Constellation Visibility

### 4.1 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.

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