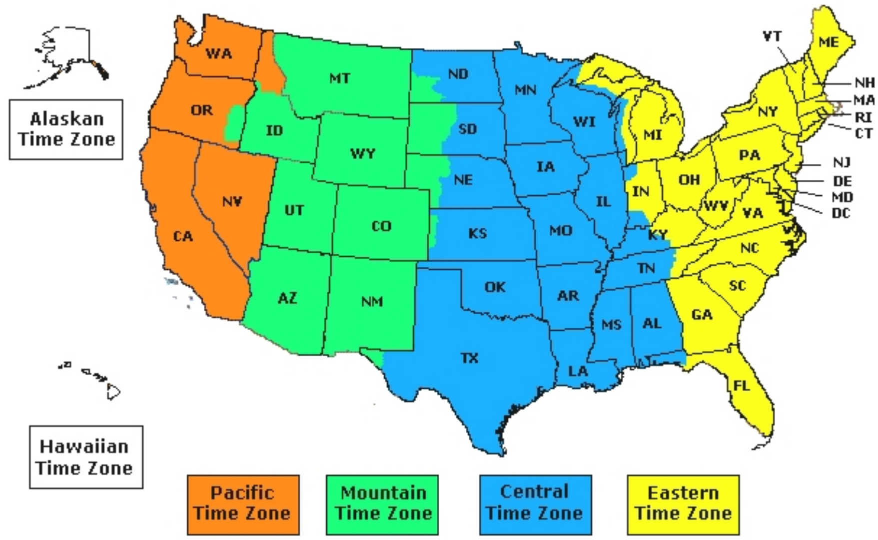
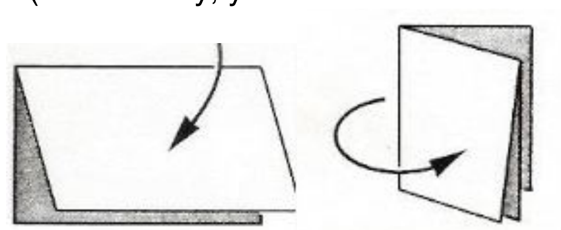
Activity 5: The Daytime Sky



Materials:
- Globe
- LEGO Minifigure
- Light bulb
- Piece of paper

Today we will talk about the sky and the motions of objects in the sky, starting with the Sun.

You will need a globe, a toy figure or something to represent a person that has markings for the head and face, and an object to represent the Sun (such as a light bulb, but it could be anything – a computer screen could work well, for instance). You will also need a piece of paper, which you can fold in half twice (as shown below) to make a smaller rectangle (alternatively, you can use an index card if you have one).



Part 1: Day and Night [1]

In this part, we will start with an extremely simple model of the Sun and Earth. In our model, we'll include someone standing on Earth's surface to help us understand what someone sees in the sky. The model looks like this:

- A light bulb (or any object, perhaps a computer screen) represents the Sun.
- Your head represents the Earth, with the top of your head being the North Pole.
- Your nose represents a mountain on Earth and our imaginary person is standing on the peak of the mountain (so that the crown of their head is pointing away from your face).

[1] This part adapted from *Earth, Moon, and Stars (Great Explorations in Math and Science)* by Cary Ivan Sneider

STEP 1: Face the model Sun (light bulb or computer screen).

For the person standing on your nose, where in the sky is the Sun? In other words, in what direction would they have to look to see the Sun?

The time of day for the person on your nose is what we call *noon*.

Noon

When the Sun is directly overhead, we call that **noon**.

(Important Note: In Part 4 below, we'll see that it can be noon even when the Sun is *not* directly overhead, but for now we are keeping it simple.)

Horizon

The **horizon** is the point (actually a plane) below which we cannot see anything because the Earth's surface is blocking our view.

Right now it is useful to hold your hands up next to your face (one on each side of your peripheral vision with your palms facing the same way as your face). Your hands now represent the East and West horizons for the person on your nose, in that the person on your nose cannot see anything below (behind) your hands.

STEP 2: Rotate to your left and stop when your *right ear* is facing the "Sun".

For the person standing on your nose, where in the sky is the Sun (in what direction would they have to look to see the Sun)? Directly overhead, on the horizon, or in between?

What time of day is it (use words, not numbers)?

STEP 3: Turn to your left again and stop when your back is facing the light bulb.

What time is it for the person on your nose (use words, not numbers)?

On what part of the Earth (your head) is it daytime?

STEP 4: Turn to your left and stop when your *left ear* is facing the "Sun".

For the person standing on your nose, where in the sky is the Sun? Directly overhead, on the horizon, or in between? What time of day is it?

STEP 5: Turn to your left one more time so that you are directly facing the light bulb again.

What time is it now for the person standing on your nose and therefore how much time has passed for the person on your nose during the course of this experiment?

STEP 6: Quickly repeat the above Steps again as needed to answer the following questions:

When the Sun is shining on your left ear, is it rising or setting?

When the Sun is shining on your right ear, is it rising or setting?

Imagine someone on the ceiling looking down at the top of your head (i.e., they're looking down at the North pole). As they watch you spin the way you just did, would they see you turning clockwise or counterclockwise?

Part 2: The Spinning Earth

SQ1:

a) Using the globe and your experience that the Sun rises in the East and sets in the West, figure out what direction the Earth spins. Does it spin clockwise or counter-clockwise as you look down on the North Pole? Explain your reasoning.

b) Does this agree with your answer to the last question of Part 1 above?

STEP 1: When the Sun is *directly above* San Francisco, is it also directly above New York? Use your globe to help you, if needed.

When it is noon in San Francisco, is it also noon in New York? Explain how you know. *Hint:* Refer back to your previous answer.

STEP 2: Starting the globe oriented with North America in the dark (nighttime), spin the globe in the direction that you figured out in SQ1. Where does the Sun reach *directly overhead* first, in San Francisco or in New York City?

When it is noon in San Francisco, is it later than noon or earlier than noon in New York City? Explain how you can tell based on your observations using the spinning globe.

STEP 3: If a football game is being played at 2pm in San Francisco, what time would the live broadcast be airing in New York City? Use the time zone map above (first page of the Activity) to help answer this question.

Does your previous answer agree with your answers in Step 2? How so?

STEP 4: An alternative to having time zones is to synchronize all clocks to have the *same time* everywhere on Earth at all moments. This is what we call *Universal Time (UTC)*.

Universal Time (UTC)

A single line of longitude is picked on Earth to be the **prime meridian**, which for historical reasons goes through Greenwich, England. Clocks are then synchronized all over the world such that *noon* on *every* clock in the world occurs when the Sun is at its highest point *above the prime meridian*. When it's noon in Greenwich, it's noon everywhere.

When we use Universal Time, what happens to the definition of noon? In other words, if it's noon in a given location, is the Sun directly overhead? Explain your answer.

SQ2: What is the purpose of using time zones?

SQ3: When astronomers make observations, they use Universal Time. Why do you think this is?

STEP 5: The prime meridian has its longitude set to 0°. If you travel east from the prime meridian one quarter of the way around the world, you would be at a longitude of 90° east. Can you find this meridian on your globe (it passes through Russia and China)?

Optional Challenge Question: Halfway around the world from the prime meridian is the *antimeridian*, which has a longitude of 180° and goes through the Pacific Ocean. The International Date Line runs roughly along the antimeridian. Fiji and American Samoa are islands in the Pacific Ocean about 400 miles apart and the International Date Line runs between them. What is the time difference between the two islands, and why? For a hint, take look at:

https://commons.wikimedia.org/wiki/File:International_Date_Line.png

STEP 6: Turn the globe over so that the opposite pole is on top. Assuming the Sun still rises in the East and sets in the West, which way would the Earth spin? To help you remember which way is East and West on the "upside down" Earth, place an imaginary person in TX and remember that California is to the West of TX and New York is to the East of TX. As in Step 1, look directly at the *north pole* (i.e., get underneath the globe and look up at the north pole) when you describe the Earth's direction of spin (clockwise or counter-clockwise).

Is your previous answer different than your answer in SQ1?

Using what you've just seen, does the Earth's orientation (holding the globe with north pole facing up vs. south pole facing up) make a difference as to which direction the globe turns, or where we see the sun rise and set? Why or why not?

Part 3: Path of the Sun [2]

Let's now upgrade our model from Part 1 and, instead of using your head as the Earth, we will use a globe as the Earth. For additional help in visualizing, we will use a figure (in this case, a LEGO "minifig") to represent the person standing on the Earth.

STEP 1: (Optional) Tape the minifig so that it's standing in the middle of your twice-folded piece of paper. Place the minifig so that it's facing one of the long edges of the paper. Mark the long edge that the figure faces as "North". Mark the opposite long edge as "South". Mark the short edges as "East" and "West".

STEP 2: Orient your Earth with the North Pole pointing to the ceiling. Place the paper (with minifig) somewhere on the Earth's equator, for instance in South America, Africa, or Indonesia.

Use the same object as we used in Parts 1 and 2 to represent the Sun. The folded paper represents the person's horizon, just as the palms of your hands represented the horizon in Part 1.

You can imagine that the plane of this piece of paper extends infinitely far in each of the four directions (North, South, East, West). The minifig cannot see anything that is on the opposite side of the horizon (the infinite plane) from the side where it is standing.

From the minifig's perspective, which direction is down? (Recall we discussed the definition of "down" in an earlier Activity.)

[2] This part adapted from the Hands-on-Science lab manual from UTeach, College of Natural Sciences, The University of Texas at Austin.

And therefore, regarding any objects that the minifig can't see because they're on the other side of the horizon, would the minifig say they are "above" or "below" its horizon? Why?

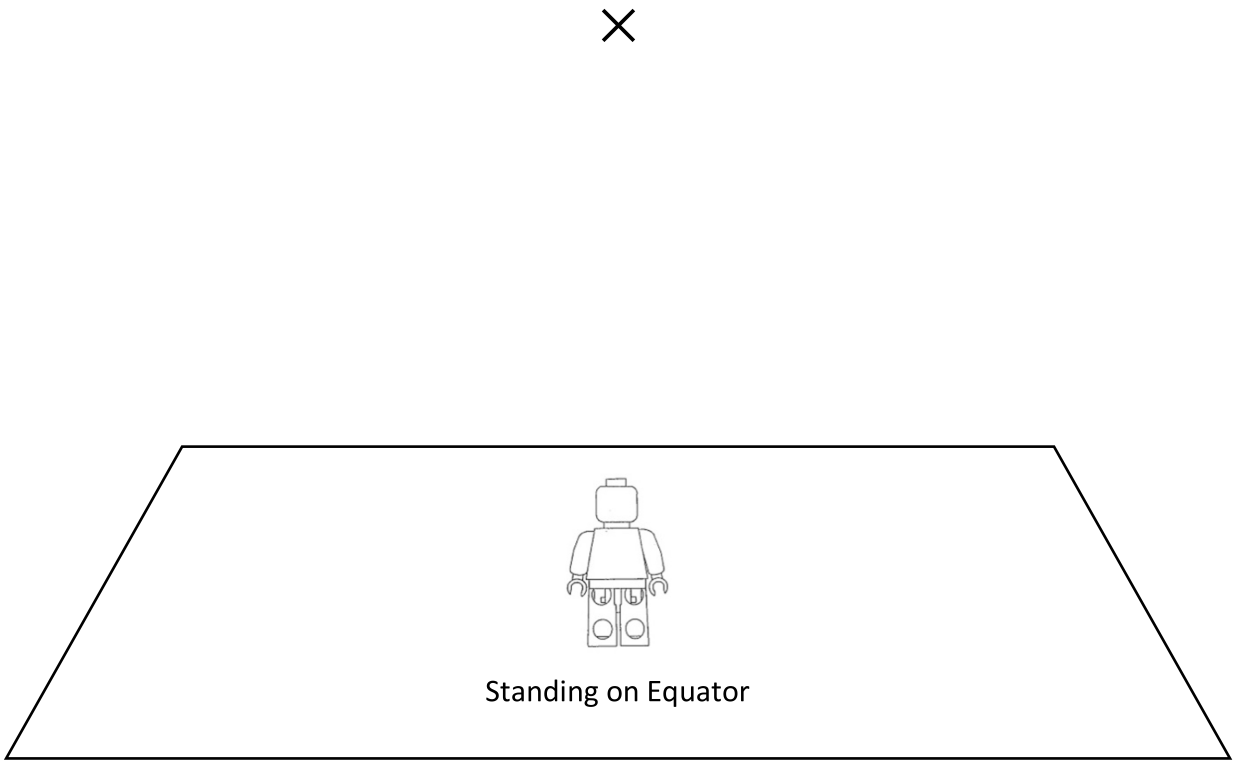
> <u>Aside on horizons</u>: In astronomy, *horizon* is used to describe any point beyond which we cannot see. The **event horizon** of a black hole is the edge of the black hole inside of which we can no longer see what's happening. The **cosmological horizon** is the farthest distance that we can see in the Universe because that's the farthest that light has been able to travel to our eyes since the Big Bang. The cosmological horizon exists at a distance of about *13.8 billion light years*. Beyond that distance, we cannot observe anything of what is occurring.

STEP 3: Below (next page) is a perspective drawing of the folded paper with the minifig standing on it. We are looking at the back of the minifig's head. In the drawing, label the edges of the folded paper with **N**, **S**, **E**, and **W**.

We will call this drawing a "*sky diagram*" and we will be using it to draw the sky as the minifig "sees" it. There are some challenges in drawing a 3D world on a 2D piece of paper, so these next points about sky diagrams are crucial:

- We are looking at the back of the minifig's head.
- An object in the sky that's seen *on the horizon* will be drawn at one of the edges of the folded paper / index card.
- An object that's visible in the sky in front of the minifig (i.e., in the direction it is looking) can be drawn above the folded paper / index card. This is the sky that the minifig "sees" and that's what we wish to draw on this diagram.
- We will not be drawing anything in the sky that is *behind* the minifig (i.e., nothing that the minifig has its back turned to).
- The ✕ above the minifig's head will represent "directly overhead" (in other words, a line extending straight up out of the minifig's head will intersect the ✕).

  Therefore, nothing should be drawn in the sky higher than the ✕. This point is called the **zenith**: it is the highest something can be overhead.



STEP 4: Returning to the actual minifig on the folded paper that is on the equator of the globe, spin the globe until the top of the minifig's head is pointing toward the "Sun". Where is the "Sun" in the minifig's sky? Answer this by drawing the Sun on the sky diagram above and label it "Position #1". To do this you may wish to review the bullet points above.

STEP 5: Now rotate the globe counter-clockwise one quarter turn.

> Important: When drawing something in the sky we need to think about *two* pieces of information: the **direction** to the object and **how high** the object is above the horizon.

Where is the Sun in the minifig's sky now? In other words, *in what direction* does the minifig have to look to see the Sun and *how high* above the horizon is the Sun in the minifig's sky? Answer this by drawing the Sun's location on the sky diagram above and label it "Position #2".

STEP 6: Rotate the globe counter-clockwise another quarter turn.

Where in the minifig's sky is the Sun now? If applicable, draw it on the sky diagram above and label it "Position #3". Review the earlier bullet points about sky diagrams if you're unsure.

STEP 7: Rotate the globe counter-clockwise another quarter turn.

Where in the minifig's sky is the Sun now? In other words, *in what direction* does the minifig have to look to see the Sun and *how high* above the horizon is the Sun in the sky? Answer this by drawing the Sun's location on the sky diagram above and label it "Position #4".

STEP 8: You should now have up to 4 locations marked on your sky diagram. "Connect the dots" of the locations you marked on the sky diagram by using a curved line to show the path of the Sun through the sky. Draw an arrow on your line to indicate the direction the Sun moved. Does the path of the Sun you've drawn roughly match what we experience in our daily lives? How so?

Have the instructor double-check your sky diagram before moving on.

This may seem like a lot of work just to say that the Sun rises in the East, gets higher and higher in the sky, then gets lower and lower in the sky, and eventually sets in the West. However, *we've done something very important here:* we've carefully drawn connections between the *two dimensional* sky (i.e., a two-dimensional hemisphere) that we see above our heads and the *three dimensional* arrangement of ourselves, the Earth, and the Sun.

Much of what we'll be doing when we study the sky will be finding ways to connect what is going on in 3D space to what we see in the 2D sky. *In many ways, this is the essence of astronomy.*

Part 4: The Sky at Different Latitudes [3]

What we've just done in Part 3 is draw the path of the Sun in the sky as seen by someone *on the equator*.

What path would the Sun take for someone that's standing somewhere else on the Earth besides the equator? We will now use the same setup as in Part 3 to explore what the sky looks like to people at different latitudes.

[3] This part adapted from the Hands-on-Science lab manual from UTeach at The University of Texas at Austin.

<u>Path of Sun as seen from North Pole</u>

STEP 1: Move the minifig and its horizon (the folded piece of paper) so that it is standing on top of the North Pole.

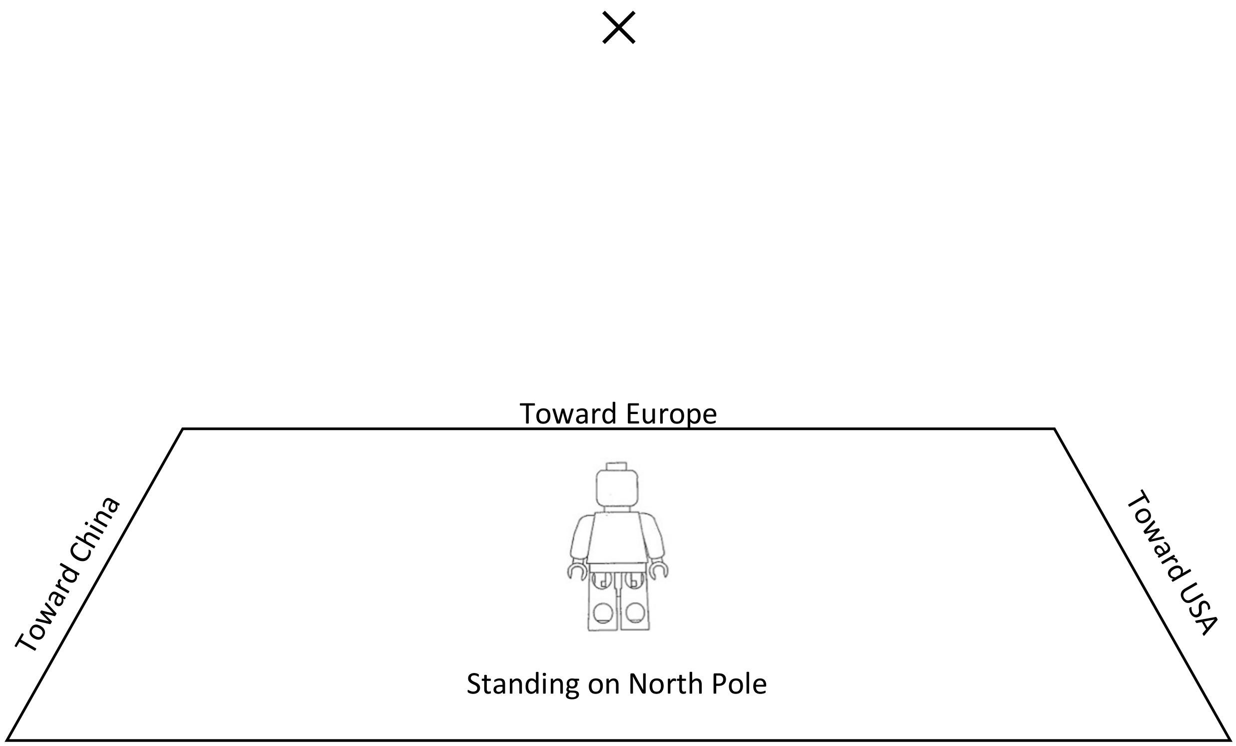
> On the surface of the Earth:
> **North** is defined as *toward the North Pole*.
> **South** is defined as *toward the South Pole*.
> **East** is defined as 90 degrees to your *right* if you are facing North.
> **West** is defined as 90 degrees to your *left* if you are facing North.

For the minifig standing *on top of the North Pole*, in which of the cardinal directions can it walk from there? Explain your reasoning. Hint: Review the definitions of the cardinal directions in the box above.

As a consequence of your previous observation, for this part of the activity we will ignore the N/S/E/W that is written on the folded paper.

STEP 2: Rotate the globe so that Europe is facing the "Sun". Then rotate the minifig so that it is facing in the direction it would need to go if it wanted to walk towards Europe.

Where in the minifig's sky is the Sun now? In other words, *in what direction* does the minifig have to look to see the Sun and *how high* above the horizon is the Sun in the sky? Answer this by drawing the Sun's location on the sky diagram below (next page) and label it "Position #1" (note that the directions have been adjusted for you in the diagram).



STEP 3: Rotate the Earth a quarter turn to the left, as we did in the previous Parts, so that the USA is facing the Sun. The minifig should still be facing in the direction of Europe.

Now where is the Sun in the minifig's sky? *In what direction* does the minifig have to look to see the Sun and *how high* above the horizon is the Sun in the sky? Answer this by drawing the Sun's location on the sky diagram above and label it "Position #2".

STEP 4: Rotate the Earth another quarter turn to the left so that the Pacific Ocean is facing the Sun.

Where in the minifig's sky is the Sun now? If applicable, draw it on the sky diagram above and label it "Position #3". Review the earlier bullet points about sky diagrams if you're unsure.

STEP 5: Rotate the Earth another quarter turn to the left so that China is facing the Sun.

Now where is the Sun in the minifig's sky? *In what direction* does the minifig have to look to see the Sun and *how high* above the horizon is the Sun in the sky? Answer this by drawing the Sun's location on the sky diagram above and label it "Position #4".

STEP 6: Finish rotating the Earth through one last quarter turn.

SQ4: Over the course of 24 hours, what is the path of the Sun in the sky for someone standing on the North Pole? When is sunset? When is sunrise? Or do these questions even make sense? Explain your reasoning.

> Important Note*:* This is not *always* what someone would experience while standing on the North Pole because we have simplified our in-class model by leaving out the *tilt of the Earth*. We will discuss the effects of Earth's tilt in more detail in a couple of weeks.

Path of Sun as seen from Mid-Latitude

STEP 7: This time let's put the minifig in Austin, TX. The minifig should still face North, therefore make sure to rotate the folded paper appropriately so that the directions on the paper match those of the globe (recall the definition of North, South, etc. from earlier).

Rotate the globe so that the USA is facing the Sun.

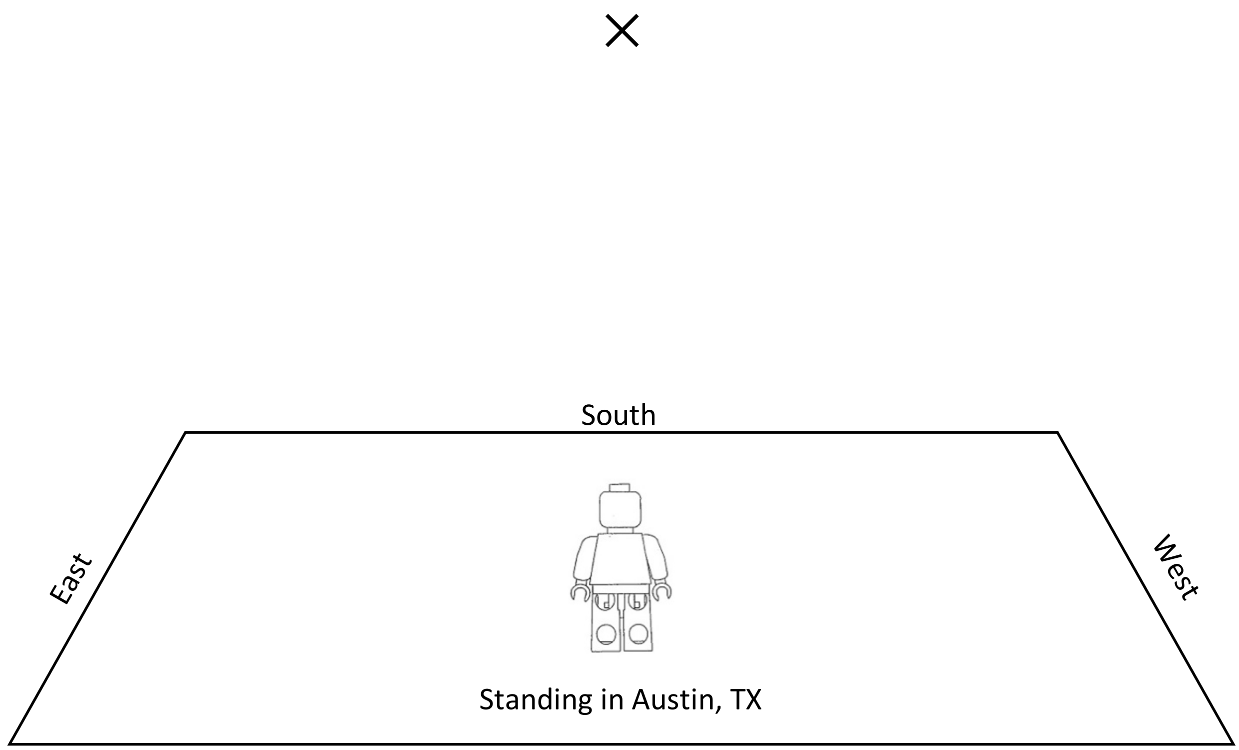
For the minifig facing North in Austin, TX, can it see the Sun without turning around and without doing a back bend? Explain why or why not.

What direction would the minifig need to face to be facing the Sun? Or in other words, which way does the minifig need to face for the Sun to be shining on his/her face?

STEP 8: Let's adjust the facing of the minifig so that it can see the Sun. However, we can't just rotate the piece of paper, because the paper already has N, S, E, and W labeled on it and those correspond to directions on the globe. Instead, let's remove the minifig from the paper, rotate it, and then place it back on the paper facing the needed direction in order to face the Sun.

STEP 9: With the USA still facing the Sun and the minifig in Austin, TX, where in the minifig's sky is the Sun? Draw its location on the sky diagram below, making sure to correctly represent the Sun's direction and height, and label this "Position #1".

Notice: The sky diagram has been labeled for you in a way that shows that the minifig is now *facing South*. Double check that your minifig is facing South on the globe.



STEP 10: Rotate the globe through a quarter of a day.

Now where in the minifig's sky is the Sun? Draw its location on the sky diagram above (if applicable), making sure to correctly represent the Sun's *direction* and *height*, and label this "Position #2".

STEP 11: Rotate the globe another quarter of a day.

Now where in the minifig's sky is the Sun? Draw its location on the sky diagram above (if applicable), making sure to correctly represent the Sun's *direction* and *height*, and label this "Position #3".

STEP 12: Rotate the globe another quarter of a day.

Now where in the minifig's sky is the Sun? Draw its location on the sky diagram above (if applicable), making sure to correctly represent the Sun's *direction* and *height*, and label this "Position #4".

STEP 13: Connect the dots to draw the path of the Sun through the sky for an observer facing South in Austin, TX.

SQ5: How is the path of the Sun for an observer in Austin similar to the path of the Sun for an observer on the equator? How is it different?

Wrapping it Up

SQ6: If you are standing in the Northern hemisphere, in what direction would you have to face in order to face the Sun? And in the Southern hemisphere, in what direction would you have to face in order to face the Sun?

SQ7: Look back at what you've learned in this activity to complete the summarizing table below (next page). For the latitude of each observer, look at the markings on the globe. What is the latitude of the equator? What is the latitude of the North Pole? The latitude of Austin has been done for you.

Use a phrase or sentence to describe the path of the Sun at each latitude.

Observer	Latitude	Path of Sun	
Equator			
North Pole			
Austin, TX	30° N		

Label the 4th column with the header **Max Height of Sun**. The units for this column will be in *degrees*. If the Sun is directly overhead, its height is 90°. If it is on the horizon, its height is 0°.

Now fill in the 4th column. Once you've done the Equator and North Pole, look for the pattern and then make a guess as to the Sun's maximum height for Austin.

SQ8:

a) What changes about the motion and/or position of the Sun in your sky as your latitude (distance from the equator) increases?

b) What doesn't change?

Important Note about Earth's Tilt:

As mentioned earlier, we have not incorporated the tilt of the Earth's axis into our model in this Activity. We will add the tilt to our model in a couple of weeks. What we've modeled today is effectively what happens on the **equinoxes** (twice a year) and we'll return to the idea of equinoxes when we talk about the Earth's tilt.