Activity 6: The Nighttime Sky

"The Starry Night" by Vincent van Gogh

Materials:
- Globe
- LEGO Minifigure
- Piece of paper folded twice
- Light bulb (or other object to be the Sun)

Part 1: Paths of the Stars [1]

In this Part, we will use the same setup as in the previous Activity. The globe will model the Earth, a light bulb will model the Sun, and we will use a minifig to represent a person standing on the Earth. This time, however, we will introduce another object into our model: the North Star.

As a setup reminder: the minifig should be in the middle of a twice-folded piece of paper (or index card). The edges of the paper should be labeled N, S, E, and W. For this activity, the minifig should be *facing North*.

As before we will be using *sky diagrams* to draw what the minifig sees in its sky. In case you need to review them, here are the rules of thumb for drawing sky diagrams:

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

STEP 1: Choose an object above your head or on the ceiling. This object will represent the **North Star** in our model. Position your globe so that its North Pole is directly

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

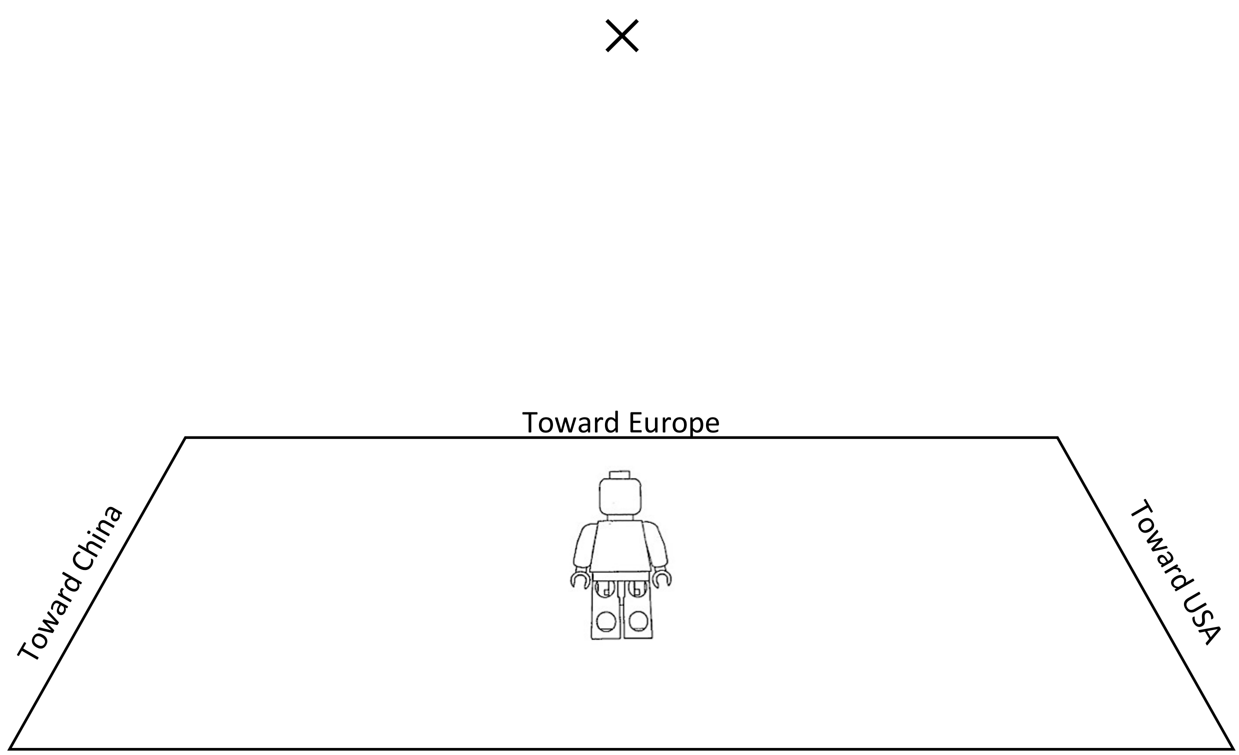
underneath the “North Star”. In other words, if you extend an imaginary line straight out of the North Pole, that line should intersect the North Star.

Recalling what we learned earlier this semester about distances and scale, is the distance to the North Star to scale in our model? Why or why not?

Is the size of the North Star to scale? Why or why not? (Note: As we’ll learn later in this course, the North Star is significantly larger than the Sun.)

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

Place the minifig on the North Pole. Rotate the Earth so that Europe is facing the Sun and then rotate the minifig on the North Pole so that it’s facing toward Europe. Where in the sky is the North Star? Mark it on your sky diagram below. Review the earlier bullet points about sky diagrams if needed.



STEP 2: Rotate the Earth a quarter turn to the left so that the USA is facing the Sun. The minifig is still facing Europe. Where in the sky is the North Star? Mark it on your sky diagram above, if needed.

STEP 3: Repeat Step 2 three more times (turning the globe a quarter turn and then noting the location of the North Star) so that the Earth has completed one revolution.

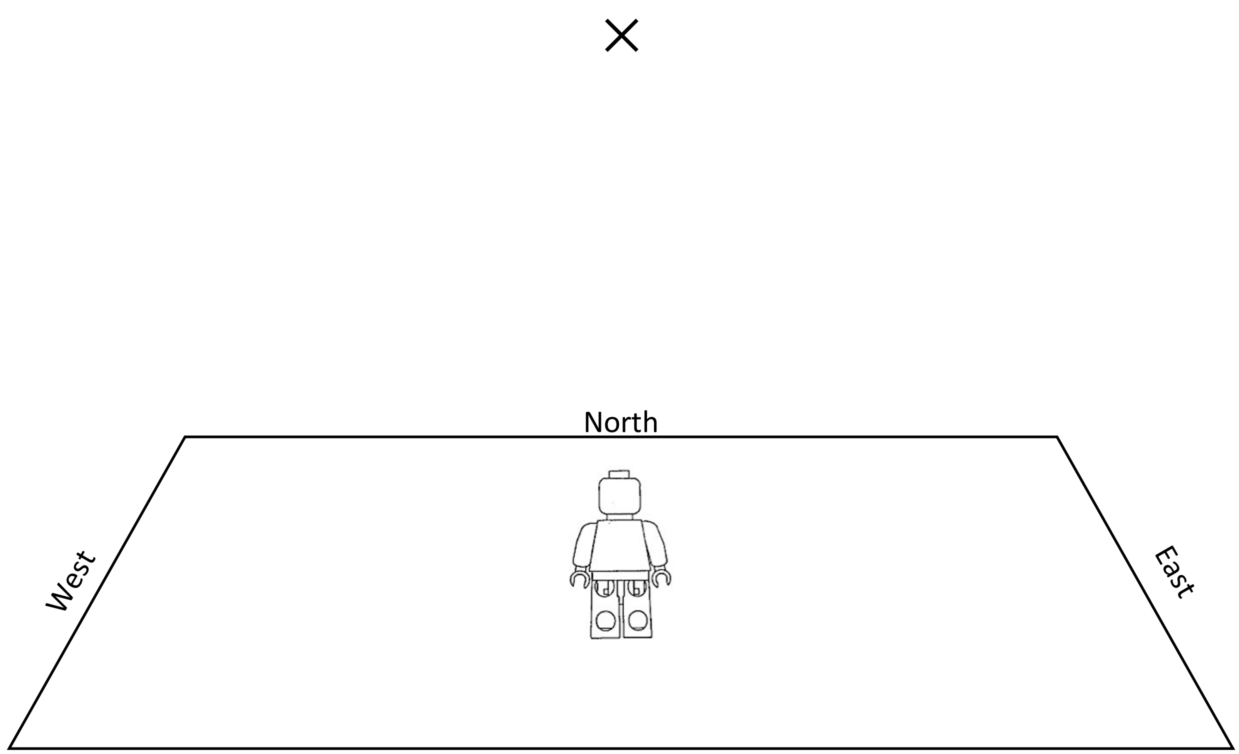
SQ1: Over the course of 24 hours, what is the motion and/or location of the North Star in the sky for someone standing on the North Pole?

<u>Path of North Star as seen from Mid-Latitude</u>

STEP 4: Now let's move the minifig to Austin, TX. The minifig should face North, therefore make sure to rotate the index card appropriately so that the directions on the card match the globe (recall the definition of North, South, etc. from earlier) and the minifig is facing North.

Rotate the globe so that the USA is facing the Sun. The North Pole is still lined up with the North Star.

Where is the North Star in the minifig's sky? *In what direction* does the minifig have to look to see the North Star and *how high* above the horizon is the North Star in the sky? Answer this by drawing the North Star's location on the sky diagram below.



STEP 5: Rotate the globe a quarter day counter-clockwise (some part of Asia or the Pacific should be facing the Sun now). Now where is the North Star in the minifig's sky? Draw it on your sky diagram above, if needed.

STEP 6: Finish rotating the Earth through the course of 24 hours and monitor the location of the North Star in the minifig's sky. Mark the location of the North Star on your diagram for every quarter turn of the globe.

SQ2: Describe the motion and/or position of the North Star for someone at mid-latitude. Be sure to mention height, direction, and motion, where applicable.

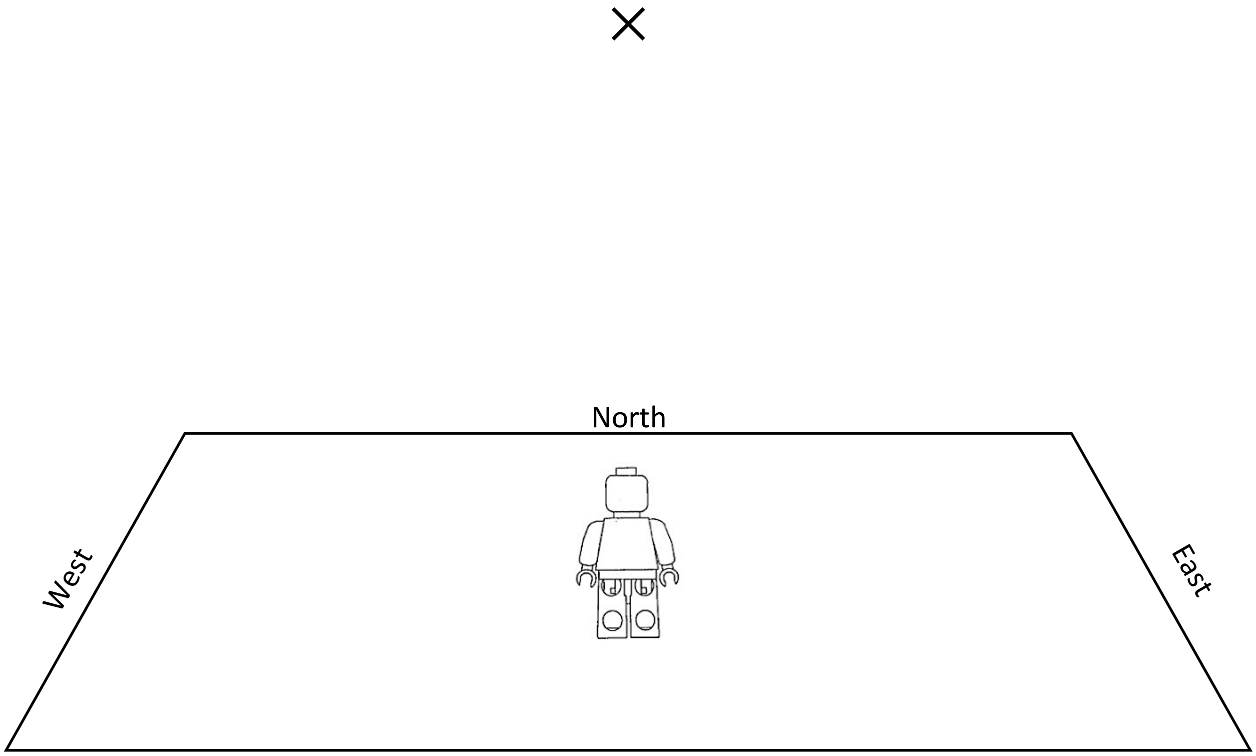
Paths of Other Stars

Do you think all stars have paths through the sky similar to the North Star's? Why or why not? Write down your hypothesis and keep going.

STEP 7: Now test your hypothesis. Keep the globe's North Pole lined up with the North Star as before and keep the minifig facing North from Austin, TX.

Now pick another object on the ceiling. That will be a star *other than* the North Star in our model. Watch the motion of this star in the minifig's sky as the Earth rotates through 24 hours. This part can be tricky, so proceed carefully.

STEP 8: Draw the approximate position of the star in the minifig's sky using the sky diagram below. As the Earth rotates through 24 hours, pick 3 or 4 positions of the star and then connect them with a smooth, curved line. In this case, it's okay to go "above" the zenith in the diagram (this is equivalent to the minifig looking over its shoulder or bending over backwards to follow the path of the star).



STEP 9: Also draw and label the position of the North Star in the minifig's sky on the same sky diagram.

Is the star's motion the same as the North Star's? If not, what is this star's motion like relative to the North Star?

Below is a time-lapse photograph taken of the night sky over at least a 24 hour period. Let's interpret this photo.

What is the star in the center that doesn't move? Why do you think so?

Describe the motion of the rest of the stars.

Hopefully, your last answer roughly matches with what you observed in Steps 7 through 9 when tracking the path of a star in the sky. If it doesn't, talk to your instructor about your procedure in Steps 7 through 9.

Using the North Star for Navigation

SQ3: What changes and what stays the same about the North Star as your latitude (distance from the equator) increases? Does its height change? Does its direction change? Does its motion change?

Based on your previous answer, why do you think the North Star is so useful for navigators?

SQ4: Polaris is just one star of many in the night sky. What about the North Star's position relative to the Earth makes it special? Hint: Think about how we did the initial setup of the model that we used in this Part.

STEP 10: With the Earth's North Pole still lined up with the North Star, move the minifig to any spot on the Southern Hemisphere.

Where in the minifig's sky is the North Star now? Remember: the folded piece of paper (extended to infinity) is the horizon. The minifig can't see anything below the horizon (i.e., on the opposite side of the paper from the minifig).

The North Star is a bright star in the sky that just happens to line up with the North Pole. The North Star cannot be seen in the Southern Hemisphere, but is there a South Star? With as many stars as there are in the Universe it comes as no surprise that yes, there is a star that lines up perfectly with the South Pole. How might the South Star be used in the Southern Hemisphere for navigation?

The South Star is actually too dim to be seen without a telescope, so it's not very useful to navigators! However, the South Star is centered inside a constellation that *is* very bright and easy to see. This constellation, which is cross- or kite-shaped (see photo at right), is called the **Southern Cross** (also called **Crux**). Navigators in the Southern Hemisphere can therefore make use of the Southern Cross in the same way that navigators in the Northern Hemisphere use the North Star.

Southern Cross

Part 2: The Night Sky and Latitude [2]

Space Diagrams and Sky Diagrams

We're now going to take a deeper look into the night sky and how it changes with latitude. As a warmup, let's follow the Sun's path through the sky for someone standing on the equator. You may use your globe and minifig to model this if you like, but we will also be drawing the scenario "from space".

Below is a "**space diagram**" which indicates the positions of the Sun and Earth. The minifig is standing on the equator and facing North.

Is this diagram to scale? Why or why not?

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

STEP 1: Since the minifig in the space diagram (previous page) is standing *on the equator* and *facing North*, where is the North Pole in the drawing? Mark and label it. Remember: the Earth looks like a circle in the diagram but it is actually a sphere. If you're unsure where the North Pole is, first try to recreate this scene with your globe and then ask yourself the question again.

STEP 2: Recall in the last Activity we figured out which direction the Earth rotates when viewed looking directly at the North Pole. Draw a short curved arrow to indicate the direction of Earth's rotation on the space diagram above.

STEP 3: On the diagram, draw the piece of paper on which the minifig is standing (since you are looking at the paper edge-on then you can just draw it as a straight line).

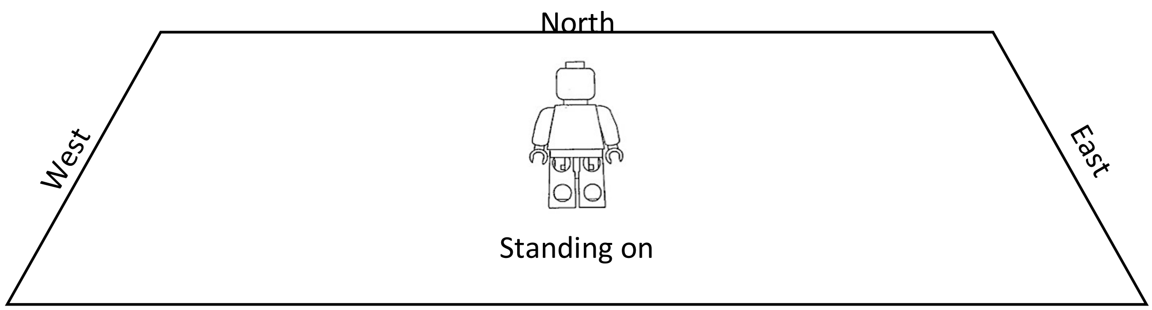
STEP 4: Label East and West on the straight line as **E** and **W**. Hint: Imagine the minifig is standing in the middle of the USA and facing North. Which way would it walk to get to the West Coast, to its left or to its right? Which way would it walk to get to the East Coast?

STEP 5: Extend your straight line to "infinity" (i.e., the edge of the space diagram) in both directions.

As before, the paper (drawn as a straight line here) represents the *horizon*. Remember, anything "below" the horizon ("down" from the minifig's perspective) cannot be seen by the minifig.

STEP 6: Where is the Sun in the minifig's sky? *In what direction* would it have to look, and *how high* above the horizon? Draw the Sun in the appropriate location on the sky diagram below and label it "Position #1".

What time of day is it for the minifig?



STEP 7: Imagine 6 hours have elapsed. Draw an X to represent the minifig's new position in the space diagram below. As before, draw the minifig's horizon (extending it to the edges of the space diagram) and denote the directions **E** and **W** on the horizon.

STEP 8: Where is the Sun in the minifig's sky? *In what direction* would it have to look, and *how high* above the horizon is it? Draw the Sun in the appropriate location on the *previous sky diagram* and label it "Position #2".

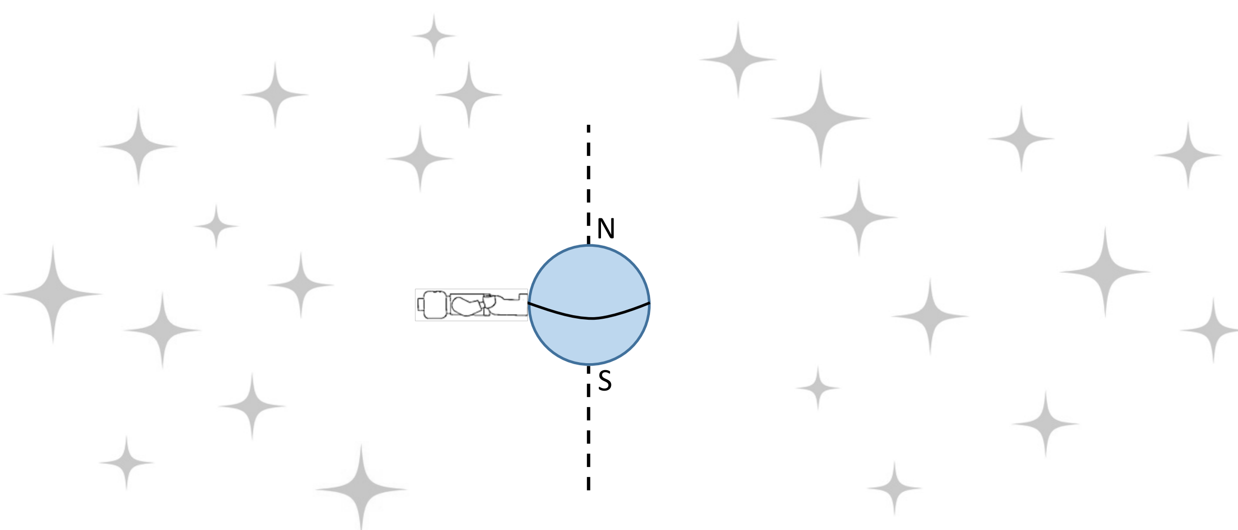
STEP 9: Repeat the previous two Steps: Another 6 hours elapse. Draw the location of the minifig on the *space diagram below*. Draw and label its horizon. Return to the *sky diagram above* and draw the Sun in the appropriate location and label it "Position #3".

STEP 10: Another 6 hours elapse. Without drawing it on a space diagram, where is the Sun going to be in the minifig's sky?

Observing the Stars from the Equator

Now that we've warmed up to correlating space and sky diagrams using something familiar (the Sun), let's now use this technique to consider the night sky for an observer on the equator.

Look at the space diagram below. The minifig is still standing on the equator and is still facing North, but now we are looking at things from a different angle. The axis of rotation for the Earth has been marked with a dashed line. The North and South poles have been labeled. The equator is indicated by a solid line. We are assuming it is nighttime so that the minifig can see the stars.



Is this drawing to scale? Why or why not? Mention both distances and sizes, in particular the size and distance of the stars relative to the Earth (this will be important later).

STEP 1: Draw a small curved arrow next to the Earth's axis to indicate the direction of its rotation (for this, picture it in three dimensions!).

STEP 2: Draw a line on the diagram to represent the observer's horizon (i.e., the paper extended to infinity).

STEP 3: What part of space is *above* its horizon? Answer this by lightly shading the region of space that is currently above its horizon.

STEP 4: Now imagine the Earth rotates 12 hours. Where is the minifig now? Draw an X on the space diagram above to indicate the minifig's position.

STEP 5: Let us again assume it's nighttime and the minifig can see the stars. Now what part of space is *above* its horizon? Answer this by lightly shading the region of space that the minifig can currently see above its horizon.

To help you with part (b) of the next question, let's quickly define what we mean by "rise" and "set".

Rising and Setting

An object **rises** when it goes from being *below* an observer's horizon to being *above* the observer's horizon. An object **sets** when it goes from being *above* an observer's horizon to being *below* the observer's horizon.

SQ5 Answer the following three questions for the minifig standing on the equator. For all of the questions let's assume that the minifig can see a starry sky at all hours of the day (i.e., the daytime sky never blocks the view of the stars).

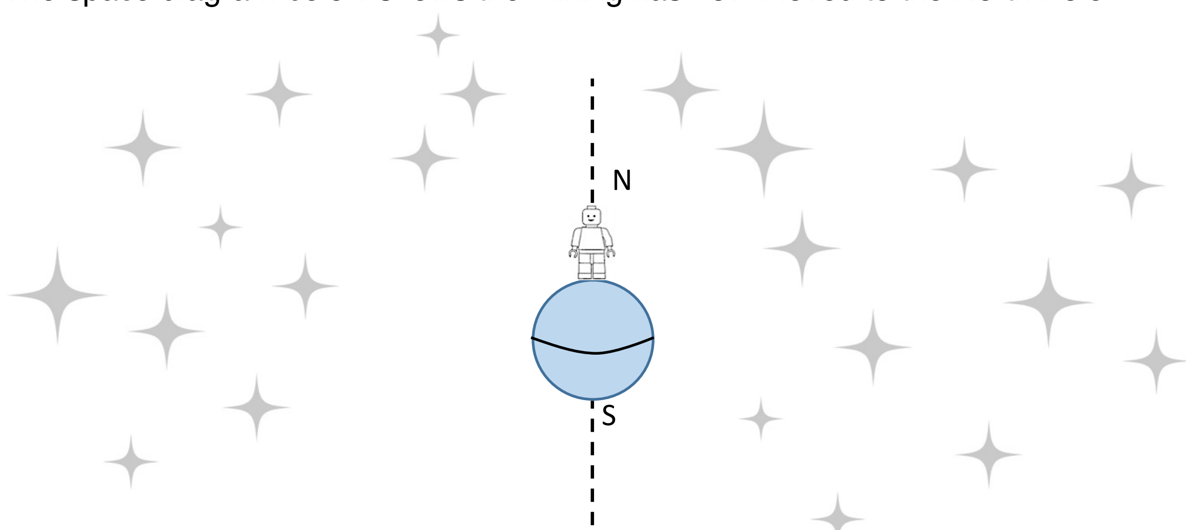
(a) Is every star visible to the minifig at some point during the course of 24 hours, or are there some stars that the minifig will *never* see? How can you tell?

(b) Are there any stars that rise and set for the minifig on the equator? How can you tell?

(c) Roughly what fraction of space will the minifig be able to see over the course of 24 hours?

Observing the Stars from the North Pole

The space diagram below shows the minifig has now moved to the North Pole.



STEP 1: Draw a curved arrow to represent the direction of the Earth's rotation.

STEP 2: Draw a line on the diagram to represent the minifig's horizon (i.e., the paper extended to infinity).

If it is allowed to turn, bend, and look in any direction, how much of space can the minifig see at this time? Answer this by lightly shading the region of space that is *above* the minifig's current horizon.

STEP 3: As before, imagine 12 hours now have elapsed.

Where is the minifig located now?

Has the minifig's horizon moved (i.e., does it need to be redrawn)?

If it is allowed to turn, bend, and look in any direction, how much of space can the minifig see at this time? Answer this by lightly shading the region of space that is above the minifig's current horizon.

SQ6 Answer the following three questions for the minifig standing on the North Pole. For all of the questions let's assume that the minifig can see a starry sky at all hours of the day (i.e., the daytime sky never blocks the view of the stars).

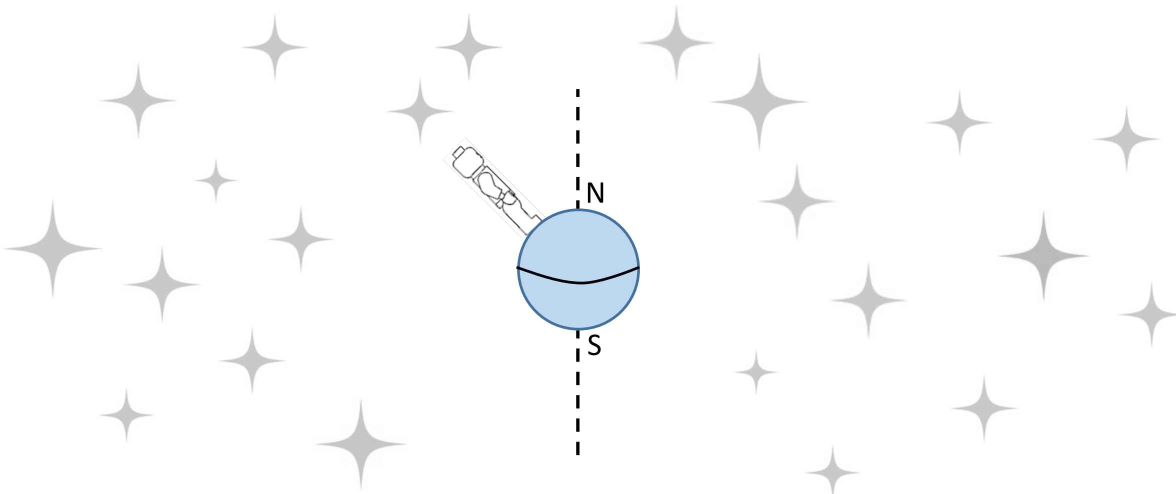
(a) Is every star visible to the minifig at some point during the course of 24 hours, or are there some stars that the minifig will *never* see? How can you tell?

(b) Are there any stars that rise and set for the minifig on the North Pole? How can you tell?

(c) Roughly what fraction of space will the minifig be able to see over the course of 24 hours?

Observing the Stars from Mid-Latitude

The space diagram below shows the minifig has now moved to some mid-latitude in the Northern Hemisphere.



STEP 1: Draw a curved arrow to represent the direction of the Earth's rotation.

STEP 2: Draw a line on the diagram to represent the minifig's horizon (i.e., the paper extended to infinity).

If it is allowed to turn, bend, and look in any direction, how much of space can the minifig see at this time? Answer this by lightly shading the region of space that is above the minifig's current horizon.

STEP 3: As before, imagine 12 hours now elapse.

Where is the minifig located now? Draw an X on the space diagram to indicate the minifig's current position.

STEP 4: Draw the minifig's current horizon.

If it is allowed to turn, bend, and look in any direction, how much of space can the minifig see at this time? Answer this by lightly shading the region of space that is above the minifig's current horizon.

SQ7 Answer the following three questions for the minifig standing at mid-latitude. For all of the questions let's assume that the minifig can see a starry sky at all hours of the day (i.e., the daytime sky never blocks the view of the stars).

(a) Is every star visible to the minifig at some point during the course of 24 hours, or are there some stars that the minifig will *never* see? How can you tell?

(b) Are there any stars that rise and set for the minifig at mid-latitude? How can you tell?

(c) Roughly what fraction of space will the minifig be able to see over the course of 24 hours?

Are there some stars that are *always* above the minfig's horizon?

If so, what portion of your space diagram corresponds to those stars? Answer this by labeling the region on your space diagram.

And, what would this imply about the visibility of those stars over a 24 hour period?

SQ8 Using the time-lapse photograph above, answer the following three questions:

(a) Are there some stars that *never set* over the course of 24 hours? How can you tell from the photo? Which part(s) of your previous space diagram on page 14 would correspond to this collection of stars?

(b) Are there some stars that *do rise and set* over the course of 24 hours? How can you tell from the photo? Which part(s) of your space diagram on page 14 would correspond to this collection of stars?

(c) Based on what we've learned today about the night sky and latitude, from what latitude do you think this photograph was taken? You can answer by simply saying "on the equator" (0°), "on the North Pole" (90°), or "mid-latitude" (somewhere between 0° and 90°). How can you tell?