Questions

How does a stick's shadow behave as observed from North Carolina?

Materials Needed

For this activity, you will need the following materials:

- a simulation of a stick's shadow
- a ruler
- a pencil (do not use ink)
- the ability to read and follow directions

Points To Remember

Unless otherwise explicitly instructed, your responses must not contain personal opinions. All of your responses must be in the form of complete sentences; the fewer sentences the better. Spelling and grammar must be correct. Effective communication is essential for both learning and doing science.

Don't ask instructors for answers to questions posed in activities; you won't get them. You may ask questions regarding the clarity of the instructions or the soundness of your reasoning. If you encounter a word you are not familiar with, don't ask the instructor about it. Look it up first in your glossary and then a dictionary or some other source if necessary. Ensure that all definitions are unanimously agreed upon before proceeding. There are, of course, sound reasons for these policies. See the instructor if you have questions, but do not complain about these policies. They are not negotiable.

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.

Don't rely on what you may already know or think you may already know about topics addressed in these activities. You must develop a reliance on observations rather than preconceived knowledge, which may have been incorrectly learned. With few exceptions, your observations will tell you everything you need to know. Not being able to rely on prior knowledge or the perception of prior knowledge will probably be very frustrating for you, but it is necessary for learning how to make accurate observations and how to rely on them.

Don't use any terms that have not been precisely defined, and that includes terms you may already be familiar with but haven't encountered in this course. Many scientific terms aren't used correctly by nonscientists (and sometimes even by scientists). Some terms have one meaning in science and another meaning in other disciplines. Not being able to use what you may think is correct terminology will be frustrating for you, but it's necessary if you're to form precise and correct operational definitions of technical terms. Inconsistent

and incorrect terminology can cause problems for you, but you can prevent those problems by forming good terminology habits early on in your introduction to science.

For this specific activity, do not use the terms "north," "south," "east," "west," alone or in combinations until explicitly asked to do so. When specifying times, do not use "12:00" as a substitute for "noon." Do not use "6:00 am" as a substitute for "sunrise" or "6:00 pm" as a substitute for "sunset." Do not use the terms "rotation" or "revolution" at all.

1 Shadows During Daylight

1.1 Same Location, Same Month

Select a location close to where you are right now. The precise location is not important, but try to get close to your home state. Do not change locations until instructed to do so.

Select a date around December 18. Observe the behavior of the stick's shadow for about five consecutive days. Pay particular attention to the shadow's length and direction at different times **during daylight**. As you answer the following questions, be as specific as possible but do not be too wordy. Do not use any words that either you or anyone else in your class would not understand. You must use complete sentences. Scientists keep meticulous records of everything they observe, and you should begin learning to do that too. You will need to refer back to your observations later in the course and you will have to rely on your written records. **Use complete sentences in all of your responses. Use as few sentences as possible.**

Is the shadow's length the same throughout the day? Do not mention anything about the shadow's direction.

Is the shadow's direction the same throughout the day? Do not mention anything about the shadow's length.

Does anything about the stick itself physically change during the day? If so, what? Do not mention anything about the shadow.

Does anything about the source of illumination change during the day? If so, what? Do not mention anything about the stick or the shadow.

A shadow, like anything linear, has two ends. One end never moves, at least as long as the stick never moves, and the other end is observed to move. The end that moves is called the shadow's **tip**. There is no special name for the stationary, or fixed, end.

In the space provided, sketch the path of the shadow's **tip** during daylight on any arbitrary day. Assume that you, the observer, are directly over the stick looking down on the ground. Depending on which simulation you are using, you may or may not be able to look straight down from above the stick. However, you should be able to establish the shape of the tip's path based on your observations. For consistency in comparing your drawing with other students' drawings, make sure to draw the shadow's path with the concave side toward the top of the page. You may need to look up the meaning of *concave* if you don't remember it.

Notice that the tip's path is *symmetric*. If you fold a symmetric shape onto itself over a *symmetry axis*, then one part of the shape will precisely overlap another part. Sketch the symmetry axis for the tip's path on your diagram. **USE A RULER!** The symmetry axis should be **parallel with the long side of your paper.**

Now, draw a thick dot (•) anywhere on the symmetry axis **on the convex side of the tip's path.** This dot represents the stick as seen from directly above it. Next, put four crosses (×) at arbitrary locations **on the shadow tip's path but not on the symmetry axis.** Don't make them evenly spaced. Place a fifth cross **at the intersection of the shadow tip's path and the symmetry axis.** Next, **use a ruler** to connect the dot to each of the crosses. **USE A RULER!** Each one of the segments you just drew represents the stick's shadow at different times.

Important observation: For every shadow on the left hand side of the symmetry axis, there is a corresponding shadow on the right hand side. This means that some shadow lengths occur twice during the day. Demonstrate this to yourself by picking one of the first four shadows you drew and drawing in the corresponding shadow on the opposite side of the symmetry axis.

Locate the point **on the shadow tip's path** for which the length has a unique value (a value that is not duplicated at all during daylight). Clearly articulate how the length of this shadow compares to the lengths of all the other shadows.

——— CHECKPOINT ———

For (hopefully) obvious reasons, from now on we will call **this particular shadow** the **minimum length shadow.** If this new term causes you to want to change your answer to the previous question, you may go back and change it now.

1.2 Some Elementary Definitions

1.2.1 Shadows Connect Sky With Ground

The shortest possible length a stick's shadow can have is zero. It makes no physical sense to speak of a negative length. Think about where Sun would have to be on the sky for the shadow to vanish (have zero length).

Describe where Sun would have to be on the sky for the shadow to vanish. **Use only a single complete sentence.**

Now, what if Sun **were not** precisely where it needs to be for the stick's shadow to vanish (have zero length) but close to that place? Describe the resulting shadow **using only a single complete sentence.** Don't mention anything but the shadow. Don't mention the stick and don't mention Sun.

To get this shadow, is Sun high on the sky or low on the sky? **Use only a single complete sentence.** (Hint: You must tilt your head back to see something that is *high on the sky.*)

Now think about the shadows in the early morning and late afternoon. How do the lengths of these shadows compare to the length of the shadow in the previous question? **Use only a single complete sentence.**

To make these shadows, is Sun high on the sky or low on the sky? **Use only a single complete sentence.**

Now articulate the relationship between the shadow's length and Sun's position on the sky. **Use only a single complete sentence.**

1.2.2 Defining Directions

We operationally define the word **north** to mean *the direction from the stick's base to the tip of the stick's minimum length shadow.* We operationally define the word **south** to mean *the direction fro the tip of the stick's minimum length shadow to the stick's base.*

Operationally define the term **north-south line**.

Recall that you have already operationally defined the concepts of **parallel** and **perpendicular** in this course. **Using your drawing of the shadow tip's path, the concept of symmetry, and the concept of perpendicular**, operationally define the term **east-west line**. Note that you can do this without any knowledge of the concepts of **east** or **west**.

In your own words, operationally define the term **east** based on some or all of the concepts of **north**, **south**, **north-south line**, **east-west line**, **parallel**, and **perpendicular. Use only a single complete sentence.**

In your own words, operationally define the term **west** based on some or all of the concepts of **north**, **south**, **north-south line**, **east-west line**, **parallel**, and **perpendicular. Use only a single complete sentence.**

In geometry, a *plane* can be defined as *the geometrical entity containing all the points between two lines and extending beyond the lines to infinity.* The hard part of this definition is the concept of *between.* To make sure you understand it, use a ruler to draw two lines on a sheet of paper. It doesn't matter whether or not the two lines intersect. Put your pencil's tip at several points on the paper. Every point you choose lies in the *plane* defined by the two lines. Points in space above or below the paper do not lie in that plane.

Using the concepts above plus the concept of a **plane**, operationally define **horizon**.

1.2.3 Defining Noon

We define **noon** as *the instant at which the stick's shadow becomes the minimum length shadow.* This is equivalent to *the instant at which Sun reaches its highest point above the horizon.* This is not equivalent to Sun reaching **THE** highest point above the horizon (directly overhead). **Be sure you understand this distinction.** We define **midnight** as *the instant when Sun reaches its lowest point below the horizon.* We crudely define **sunrise** as *the instant when Sun is coming up over the eastern horizon.* We crudely define **sunset** as *the instant when Sun is going down over the western horizon.* There are actually very precise definitions for these two terms but these crude definitions are all we need at the moment. Notice that these definitions are not based on numbers, such as those read on a clock. Based on these definitions, answer the following questions.

Describe the general direction in which the shadow points at sunrise. Choose **only** from among the following to use in your answer: north, east, south, west, north of east, north of west, south of east, south of west.

Describe the general direction in which the shadow points at sunset. Choose **only** from among the following to use in your answer: north, east, south, west, north of east, north of west, south of east, south of west.

At what time or times of day is the shadow's length greatest?

At what time or times of day is the shadow's length least, but still visible?

Does the shadow ever vanish while Sun is above the horizon? If so, when?

Why is there no shadow at midnight? This is not a trick question, but it is important that you are able to correctly articulate the answer.

1.3 Same Location, Different Month

Now select a date around March 18 and for about five consecutive days, carry out the same observations that you did in the previous section. Remember that your location hasn't changed. If anything is different, describe it in the space provided.

1.4 Same Location, Different Month

Now select a date around June 18 and for about five consecutive days, carry out the same observations that you did in the previous section. Remember that your location hasn't changed. If anything is different, describe it in the space provided.

1.5 Same Location, Different Month

Now select a date around September 18 and for about five consecutive days, carry out the same observations that you did in the previous section. Remember that your location hasn't changed. If anything is different, describe it in the space provided.

2 Inquiry

Determine, to the nearest day, when the stick's shadow satisfies each of the following conditions as indicated in the table. If a condition is never satisfied, leave that entry's space blank. If a condition is satisfied on more than one date, give all relevant dates.

Condition	Date(s) condition is satisfied
max. angle between sunrise shadow and western half of east-west line	
min. angle between sunrise shadow and northern half of north-south line	
sunrise shadow points west	
min. angle between sunrise shadow and southern half of north-south line	
noon shadow max. length	
noon shadow min. length (but still visible)	
noon shadow vanishes	
max. angle between sunset shadow and eastern half of east-west line	
min. angle between sunset shadow and northern half of north-south line	
sunset shadow points east	
min. angle between sunset shadow and southern half of north-south line	

If these dates have any significance that you may be aware of, discuss that significance. If these dates have no significance that you know of, you may need to repeat this part.

From your observations, describe how the direction of the stick's shadow **at sunrise** varies over the course of an entire year. Use a single complete sentence. Use **only** the following directions in your answer: north, east, south, west, north of east, north of west, south of east, south of west.

From your observations, describe how the direction of the stick's shadow **at sunset** varies over the course of an entire year. Use a single complete sentence. Use **only** the following directions in your answer: north, east, south, west, north of east, north of west, south of east, south of west.

You have probably been told that Sun always rises east and always sets west. If Sun rises east, in what direction would the stick's shadow point at sunrise? Use a single complete sentence. Use **only** the following directions in your answer: north, east, south, west, north of east, north of west, south of east, south of west.

If Sun sets west, in what direction would the stick's shadow point at sunset? Use a single complete sentence. Use **only** the following directions in your answer: north, east, south, west, north of east, north of west, south of east, south of west.

Give evidence from your observations that either supports or contradicts the "fact" that Sun always rises east and sets west. Use a complete sentence.

In what direction does the stick's shadow point **at noon**? Use a single complete sentence. Use **only** the following directions in your answer: north, east, south, west, north of east, north of west, south of east, south of west.

If the stick's shadow vanished on any date or dates, list those dates here. If the stick's shadow never vanished, clearly state that here in a complete sentence.

In a single complete sentence, articulate the geometry necessary for the stick's shadow to vanish. This question has absolutely nothing to do with whether or not you actually observed the stick's shadow vanish.

Is it possible for two persons to observe the same stick's shadow simultaneously, agree on the shadow's length, but disagree on its direction? If so, describe how this could happen.

Using everything you have discovered, construct a framework that defines the behavior of a stick's shadow from the location you used in this activity.

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