Print Name ______________________________ Period _________ Date ________________

CA1 3.1: Observing Phases of the Moon Lab

Purpose: To observe changes in the phase of the moon over time.

Materials needed: Eyes, clear weather, observing notebook

Design:
Independent variable: date
Dependent variables: Position and appearance of the moon, time of day
Interfering variables: weather

Procedure:
Starting a day or two after the moon has reached new phase, observe the appearance of the moon each day for two weeks. Draw a sketch of the moon each time. Make your observations at about the same time of day. Record the following characteristics.

- Appearance (sketch)
- Approximate direction (North, South, East, etc.)
- Approximate altitude and azimuth
- Date, time, place of observation
- Horizon landmarks (houses, trees, etc.)

On the next page there are two blank pages for drawing your observations. A line is provided to represent the horizon. South is in the center of the image, East is to the right, and West is to the left, representing a view facing South.

Add local landmarks such as trees, houses, hills, etc., to indicate where your view may be obscured. It is not necessary to add a large amount of detail; we are drawing the moon, not your neighborhood *per se*.

Tip: Draw the moon tilted if it is tilted in the sky. Don't "fix" it. Use the landmarks you sketched to determine the location of the moon. When you draw the phases, draw the outline of the shape of the moon, leaving the interior blank to represent the lit side as follows.

This lab takes about five minutes per evening over two weeks. If dates are missing because of weather, your teacher may allow you to simulate the answer using Stellarium.

Print Name ______________________________ Period _________ Date ________________

CA1 3.1: Observing Phases of the Moon Lab

Directions: Put your drawing and observations below.

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EAST SOUTH

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CA1 3.1: Observing Phases of the Moon Lab

SOUTH WEST

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CA1 3.1: Observing Phases of the Moon Lab

Questions (after the observations are complete):

1. Each day the moon not only changes shape, but position. Which way does it move each day compared to its position at the same time on the previous day?

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2. What is the angle between the moon and the sun with you as a vertex when the moon appears to be a crescent?

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3. What is the angle between the moon and the sun with you as a vertex when the moon appears to be more than half lit (gibbous)?

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4. What is the angle between the moon and the sun with you as a vertex when the moon appears to be half lit (first quarter)?

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5. About how long will it take the moon to go through a cycle of phases?

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6. How long will it take the moon to go from one major phase to the next (for example, new to first quarter)?

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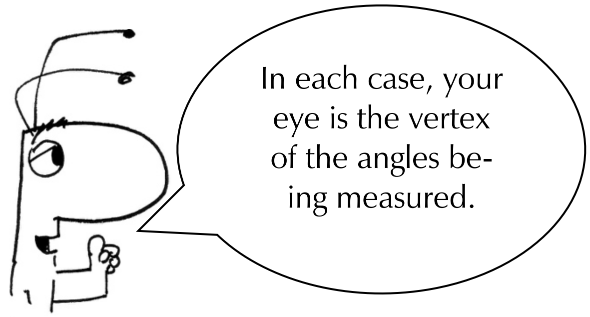
CA1 3.2: Estimating Angles Handout

Purpose: To estimate angular separation of objects using your hands.

Procedure: If you hold your arms extended, various parts of your hand are approximately equal to small angles. Taller people have longer arms and larger hands, so the ratios are approximately equal no matter how tall you are.



Hold your hand at arm's length and make a "V" with your index finger and middle finger. Tilt your wrist up so that the "V" is perpendicular to your arm like this.

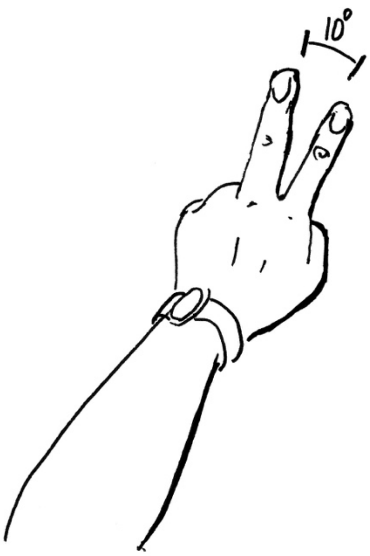


Figure 1. Estimating a 10 degree angle.

The width of the fingernail of your index finger is about 1 degree.

Figure 2. Your fingernail appears about 1 degree wide when held at arm's length.

The distance between your fingers is about 10 degrees. An interesting activity would be to measure this angle precisely in a variety of people to see how much variation you can find.

If you hold your little finger and thumb extended as far as possible, the distance between the tips of these fingers is about 20 degrees.

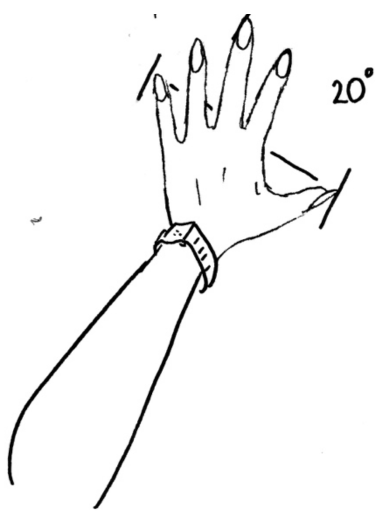


Figure 3. The distance between your thumb and little finger is roughly 20 degrees when you spread your fingers apart.

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CA1 3.2: Estimating Angles Handout

You can use this method to:

- Estimate the time remaining until sunset (the sun moves 15 degrees in one hour)
- Measure the shift of the moon with respect to the background stars from one night to the next (about 13 degrees)
- Measure the angle between the sun and moon to estimate the time a tide will occur
- What else can you come up with?

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CA1 3.3: Simulating Moon Phases and Eclipses Activity

Purpose: To simulate moon phases, lunar eclipses, and solar eclipses and emphasize the viewpoint shown in books versus what people on earth see.

Background: the phase of the moon is often explained with a handout that shows the moon going around the earth as seen from out in space from above the earth's North Pole. This perspective is helpful, but is hard to relate to the viewpoint of an observer on the earth looking at the moon. We will simulate both using a light source and some spheres and try to summarize the connection with a diagram.

Did you know you can often see the moon in broad daylight? All you have to do is look for it at the right time!

Equipment needed: Globe of the earth, sphere about 1/4 the size of the globe (preferably white or grey), bright light source such as an overhead projector

This activity has been broken into three parts:
Part 1.Phases of the moon
Part 2.Solar Eclipses
Part 3.Lunar Eclipses

Observation: Any lunar eclipse, solar eclipse, or phase of the moon can be used as an observation. *Solar* eclipses require special care to observe safely. Use the same precautions you would use when observing the sun. (CA1 2.18.)

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CA1 3.3: Simulating Moon Phases and Eclipses Activity

Moon Phases

Procedure:

1. Set up the bright light on one side of the room and illuminate the globe of the moon with it. Place the moon sphere between the light source and your head. In this position the phase of the moon is called *new moon*. The illustration shows what your classmates see when you do this. In this simulation, what represents the earth?

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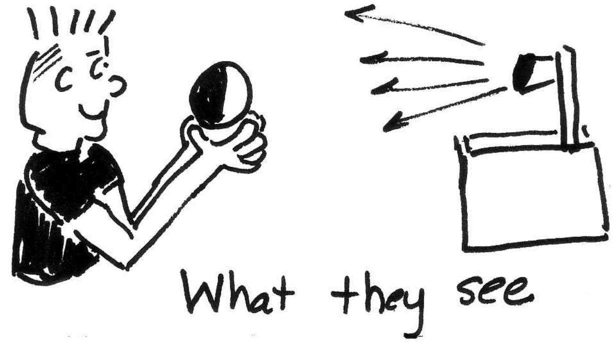

Figure 1. Simulating new moon. Your viewpoint is behind the moon, facing the sun.

2. What does the moon look like to you? Draw what you see.

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3. You are going to look at the moon from two perspectives: From above the earth's North Pole, and from the earth. This means we need a model for the earth; and what better than a globe? Put the globe where the earth was. Stand near the earth and look down on it from above. Sketch what the earth and moon look like from this vantage point.

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CA1 3.3: Simulating Moon Phases and Eclipses Activity

4. Now put your face near the globe and look at the moon again. Describe what you see.

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5. Looking at the setup from above the earth's North Pole, move the moon around the earth 1/4 of an orbit counterclockwise. You should see something like this:

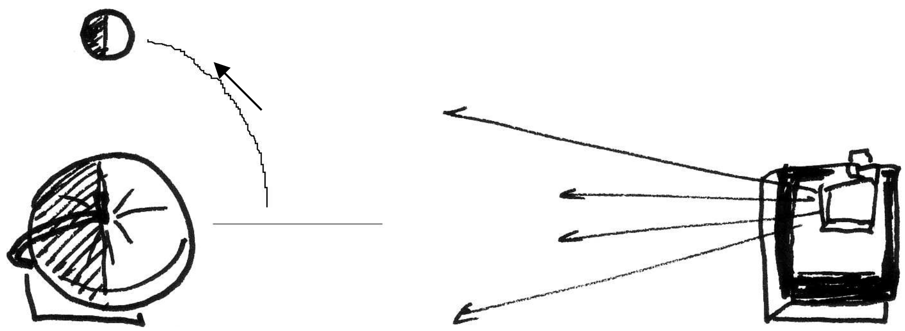

Figure 2. First quarter moon seen from above the Earth's North Pole.

6. Now try to imagine what the moon will look like from the earth's perspective and draw what you would see. Then put your face near the earth again and see if you got it right.

7. In what position(s) (again as seen from the earth) would the moon need to be in order to appear as a crescent (less than half lit)? Draw a picture to indicate these positions as seen from above the earth's North Pole.

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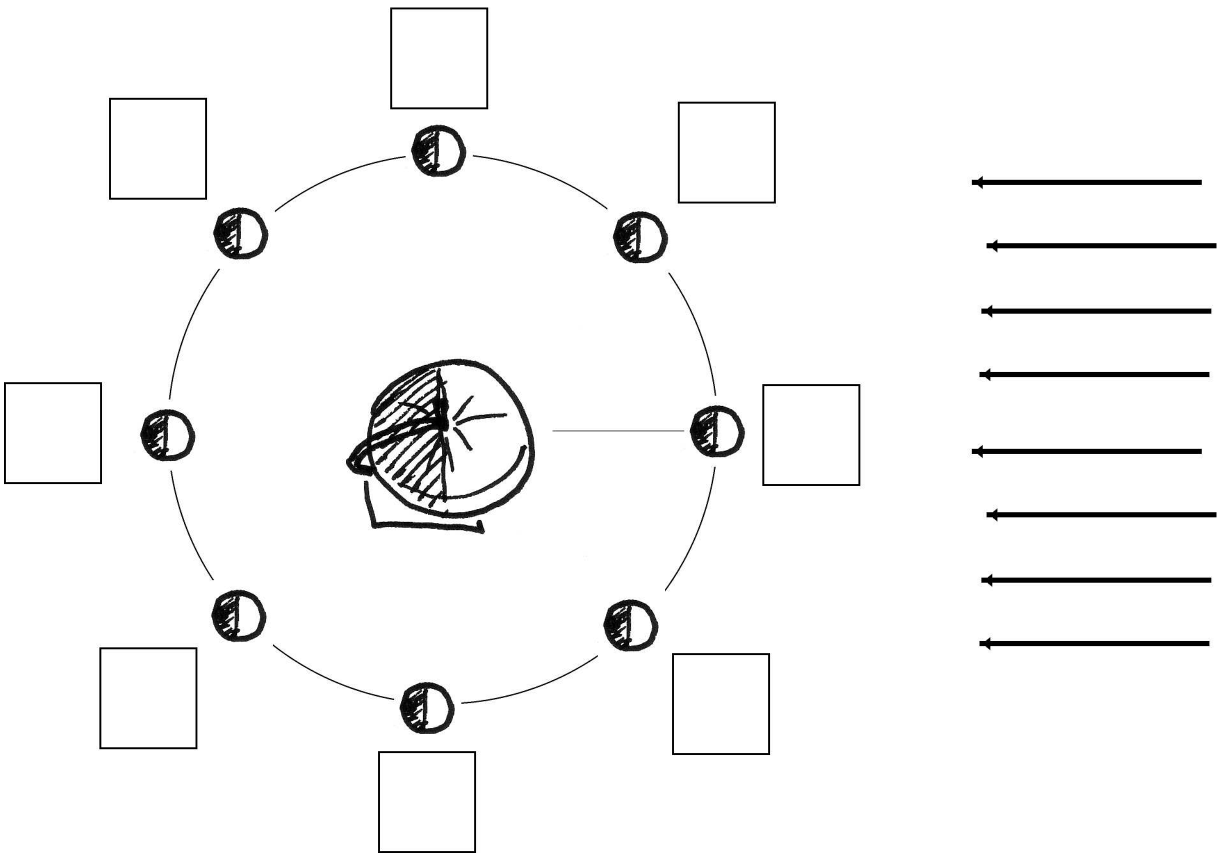
CA1 3.3: Simulating Moon Phases and Eclipses Activity

8. In a similar way, draw what you think the moon should look like *as seen from the earth* in each of the 8 positions shown in this diagram. Verify by observing from the position of the earth in your simulation. The sun is shown as a series of parallel lines because on this scale, the sun should be very far away.



Classify each picture in Figure 8 (above) as *waxing or waning*. Waxing means "getting brighter" and waning means "getting dimmer". A waxing moon will have more surface area lit and appear brighter than it did the day before.

Classify each picture as *crescent or gibbous*. Crescent means the moon is less than half-lit and gibbous means the moon is more than half lit.

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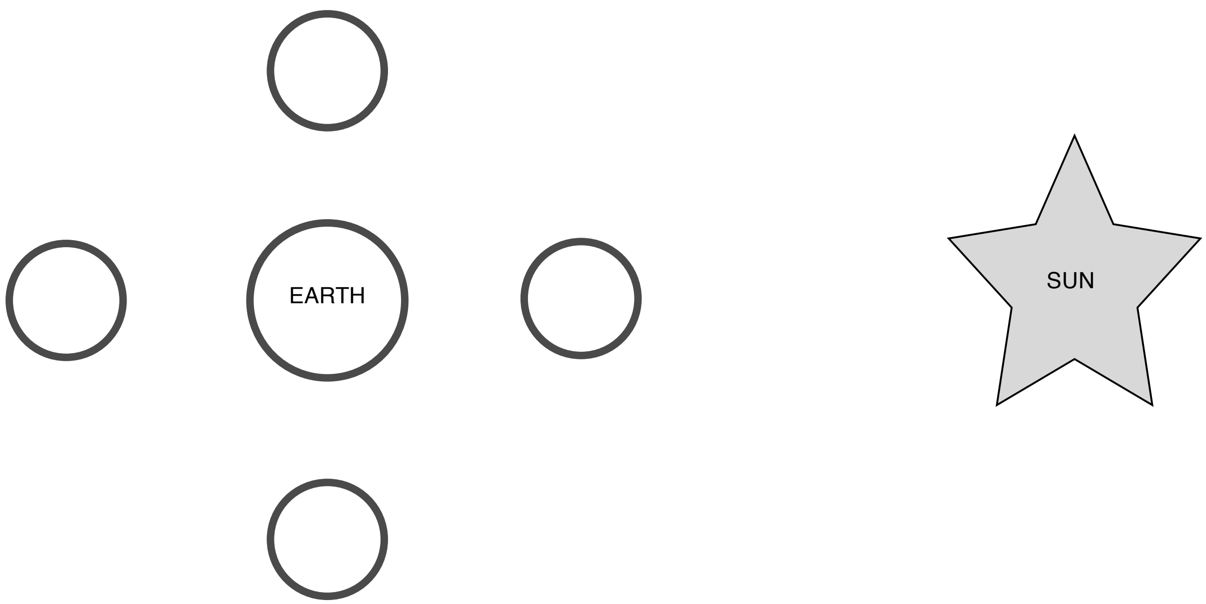
CA1 3.3: Simulating Moon Phases and Eclipses Activity

Phases which are 1/4 the way around and 3/4 the way around the earth are called *1st and 3rd quarter*, respectively. They are not classified as crescent or gibbous. And of course, when the moon is fully lit, it is called *full*. Mark your diagram with these designations.

Near side vs. far side:

As the moon orbits the earth, it keeps one side towards the earth all the time. Make a mark on your sphere model and hold it so the mark is facing you. Then move the sphere around your head, keeping the mark facing you. The side of the moon with the mark is called the near side, and that is the side always visible from the earth. The side of the moon on the other side is called the far side. That side was never seen by humans until space probes visited the moon in the 1960's.

9. Mark the drawing below (Fig. 10) with the following symbols:
Moon, sun, earth, near side, far side, lit side, dark side



Sometimes people confuse the near and far sides of the moon with the dark and lit sides. Since the moon rotates once as it goes around the earth, all sides of the moon are lit and dark eventually. When you look at the crescent moon, most of the moon is dark. That is the dark side of the moon then. When you look at the full moon, the dark side of the moon is on the other side, where you can't see it.

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Solar Eclipses

1. In this series of simulations, we're going to use your head as the earth. Hold the moon sphere up towards your light source until blocks it. Draw a picture that shows what the people around the room see when they look at you doing this.

2. Now draw a picture that represents what you see when you look at the sphere.

When the moon is in new phase, it is very difficult (nearly impossible) to observe because the sun's glare is so bright. This is why most diagrams show the new phase as a darkened circle. Sometimes the moon comes between the earth and sun so precisely, the moon covers up the sun. This is called a *total eclipse*.

Eclipses don't happen every month because the moon's orbit is tilted with respect to the earth's orbit.

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CA1 3.3: Simulating Moon Phases and Eclipses Activity

Here is a photo of a total solar eclipse. By a lucky coincidence, the moon appears to be about the same size as the sun when both are observed from the earth. The sun does not appear to be the same size as the moon anywhere else in the Solar System. When the moon covers the sun precisely, the sun is blotted out and we can see the atmosphere of the sun (called the corona). In the photo a prominence can be seen jetting out from the side of the sun.

Figure 3. A total eclipse of the sun. Photo by the author.

3. If the moon does not completely cover the sun, a partial eclipse occurs. A partial eclipse resembles a phase of the moon but looks more like someone took a bite out of the moon. Use your model to draw a progression of a partial solar eclipse.

4. When the moon is not completely covering the sun, the shadow falling on the earth is not as dark. The *umbra* of the shadow of an object is where the light source is completely blocked. The *penumbra* is where the light source is only partially blocked.

What word in the English language has the same root as umbra and describes a device used to cover you up from the falling rain?

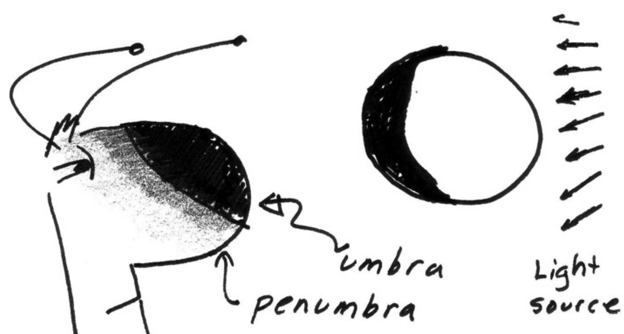

Figure 4. Cosmo's nose is in the umbra of the shadow of the sphere. His eye is in the *penumbra* of the shadow.

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CA1 3.3: Simulating Moon Phases and Eclipses Activity

To see this effect, hold the sphere so that it completely blocks the light source when seen with one eye, but does not completely block the source when you switch eyes.

Because the sun and moon appear to be the same size, the area where a person can stand on the earth and see a total eclipse is quite small—sometimes only a few miles wide.

5. Look at the diagram carefully and match the letters in the diagram with the labels below.

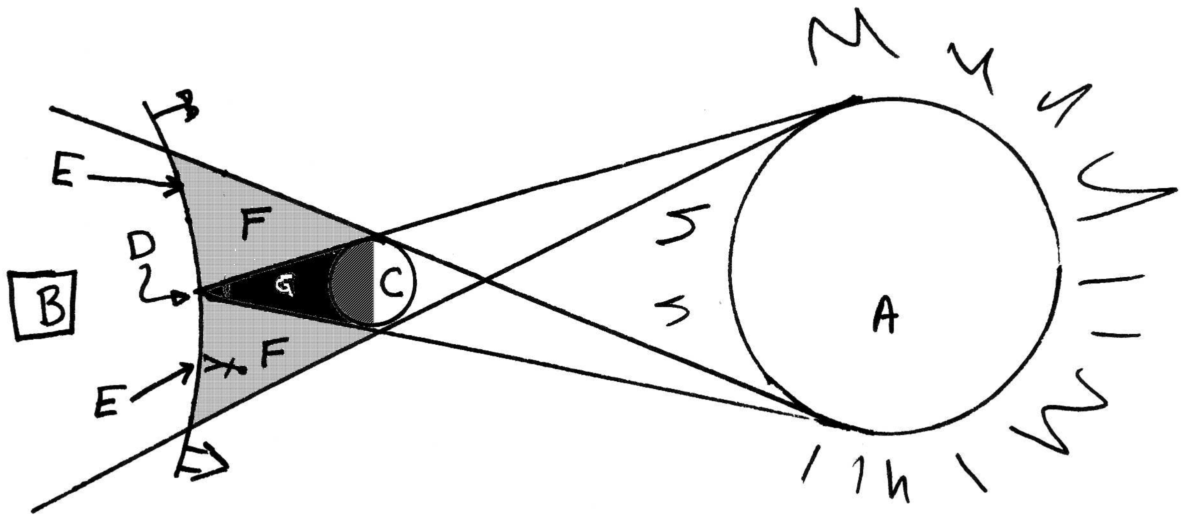

Figure 5. Geometry of a total solar eclipse.

___ Sun
___ Where you would stand on the earth to see a total solar eclipse
___ Moon
___ Where you would stand on the earth to see a partial solar eclipse
___ Earth
___ Umbra of the moon's shadow
___ Penumbra of the moon's shadow

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CA1 3.3: Simulating Moon Phases and Eclipses Activity

6. One kind of solar eclipse is called an *annular eclipse*. Because the moon's orbit is not a perfect circle, sometimes it is farther away from the earth than other times. Even when centered, the moon is not large enough to cover the entire sun.

Draw an illustration which shows the arrangement of the Earth, moon, and sun for an annular eclipse. Hint: Copy the diagram from step 7 using the same kind of alignment of lines, but move the earth farther away. Label it the same way as you did the total eclipse.

7. What would an annular eclipse look like from the earth? You may not be able to simulate this because your light source might be smaller than your sphere. Remember, the moon looks just slightly smaller than the sun in an annular eclipse.

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CA1 3.3: Simulating Moon Phases and Eclipses Activity

Lunar Eclipses

1. The other kind of eclipse is a lunar eclipse. In this case, the moon is on the other side of the earth, and falls into the earth's shadow. Lunar eclipses don't happen every month, but they do happen more frequently then solar eclipses. Identify the items labeled with letters in the diagram below.

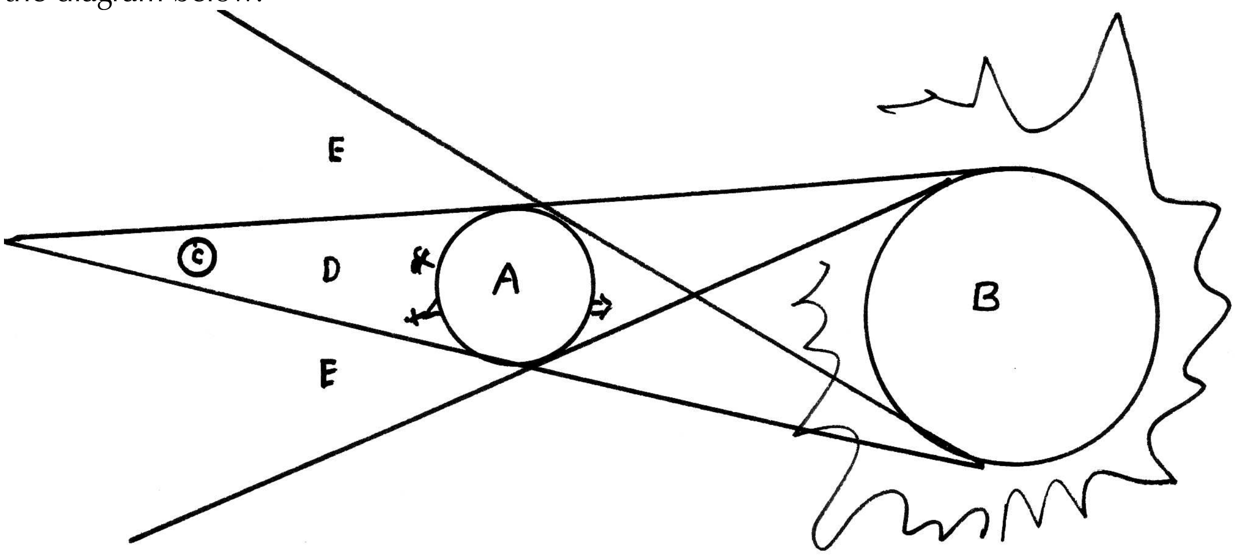

Figure 6. Geometry of a total lunar eclipse.

__ Moon
__ Sun
__ Earth
__ Umbra of the earth's shadow
__ Penumbra of the earth's shadow.

2. Look at the diagram showing the arrangement of the earth, moon and sun and suggest why lunar eclipses are more common. (Hint: use your sphere and light source to simulate the eclipse.)

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CA1 3.3: Simulating Moon Phases and Eclipses Activity

3. Lunar eclipses can be partial or total. Draw a circle on top of the diagram to show the location of the moon during a partial lunar eclipse. Why is the edge of the shadow of the earth on the moon fuzzy?

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4. Sketch a series of pictures showing what you would think the moon would look like, starting with a full moon and ending with a total lunar eclipse.

5. Sometimes lunar eclipses don't turn the moon dark; they turn it red. Why do you think the moon turns red? Hint: At what time of day do you see an eclipsed moon rise?

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6. What must the phase of the moon be during a total lunar eclipse?

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CA1 3.3: Simulating Moon Phases and Eclipses Activity

7. Here is a photograph of a lunar eclipse taken by student Richard Hamilton. If the shadow is stationary, which direction is the moon moving during the eclipse?

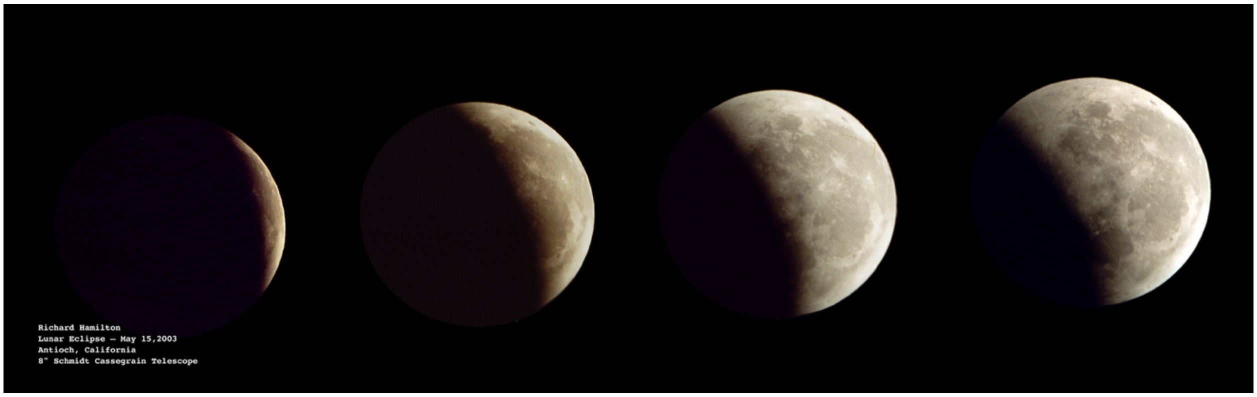

Figure 7. Lunar eclipse sequence by Richard Hamilton.

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8. Look at the curvature of the shadow compared to the curvature of the moon. Which circle is larger, and what does this imply?

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9. What is the only shape that always casts a circular shadow no matter which way you turn it? Given this fact, is it possible for the earth to be flat?

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CA1 3.3: Simulating Moon Phases and Eclipses Activity

Challenges:

1. Draw the phase of the earth as seen from the moon in each of the 8 positions.
2. Describe how the phase of the moon drove decisions about when to land on the moon.
3. Create a movie or animation to explain how the phases of the moon are related to the position of the moon.

Observation: Any solar or lunar eclipse should be good for several observations, as they are changing minute by minute.

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CA1 3.4: Explaining Moon Phases Handout

Purpose: To show why some of the alternative explanations for the moon's phases are incorrect.

Answer the questions below. Be sure to answer the question as asked. Do not answer every question with the correct explanation of why the moon has phases.

1. One explanation for moon phases often given by students is that the phases of the moon are caused by the shadow of the earth falling on the moon. Explain why this is incorrect and what this situation is actually referring to.

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2. Another explanation of the moon's phases is that the moon has a permanently dark side which is simply rotating to face us during the time it is not full. Explain why this cannot be true.

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3. A third explanation is that the shadow of the sun falls on the moon, darkening it. Explain why this is not possible.

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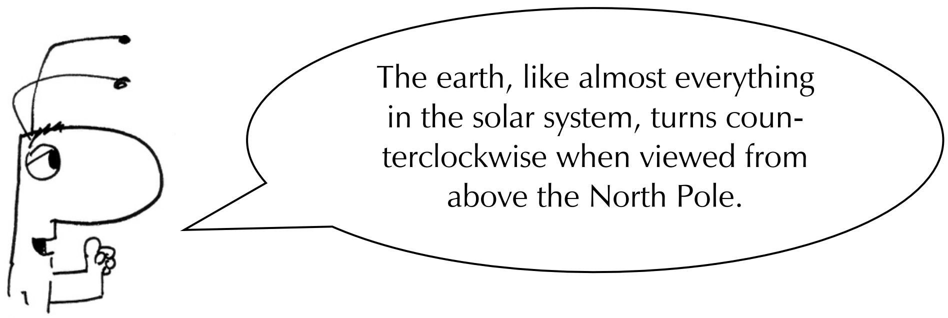
CA1 3.5: Moonrise and Moonset Activity

Purpose: To use the phase of the moon and the time of the day to predict when the moon will rise, culminate, and set.

Equipment needed: Moon Phase diagram (from activity 3-1). Globe, light source, small sphere to represent the moon.

Part One: Time of Day on the earth

The earth is a giant clock. As it rotates, parts of it turn to face the sunrise, parts of it turn away. The time of day at any location can be determined by the position of an observer on the globe.



When the observer is pointed at the sun, it is 12:00 noon. When the observer is pointed away from the sun, it is midnight. Given these facts, determine where the location of the observer when it is 6 AM and 6 PM; 3 AM and 3 PM; 9 AM and 9 PM and label them on the diagram below.

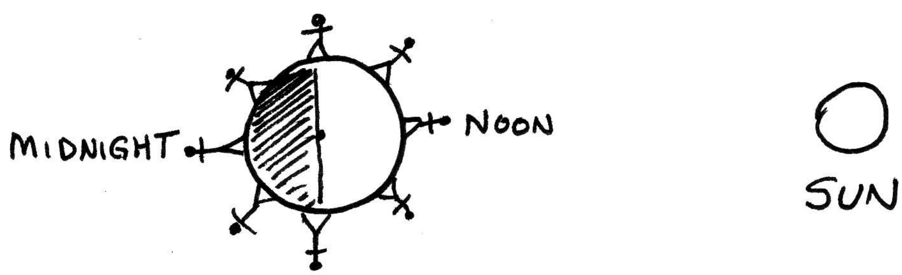


Figure 1. Time of day at various locations on the earth.

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CA1 3.5: Moonrise and Moonset Activity

The reason this works is because the observer's horizon depends on where they are on the earth. When you step outside, it looks as if the entire earth is under your feet.

Because of this effect, a person standing at one of the positions on the previous page can only see half of the sky. The half of the sky under their feet is blocked by the earth.

To see this effect, take a piece of folded paper and place it as shown on top of the diagram you drew on the previous page.

The paper represents the horizon. As you can see, the sun is above the horizon, but not as high as it can get—just as you would expect for a local solar time of 3 PM. This is the time the person's head is pointing to. Remember the earth (and the horizon paper) rotates counter clockwise.

Thus, West would be on your left and east on your right (remember we are looking on the earth from above the north pole...look at a globe and the east and west coast of the United States from above the pole and you'll see.)

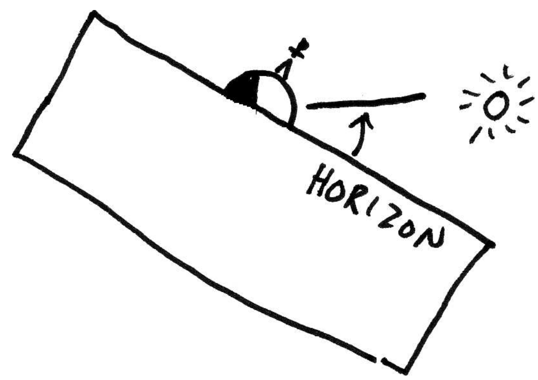

Figure 3. The horizon paper, shown here as a tilted rectangle. The angle of tilt is determined by the local time, which in turn is determined by the sun's position above the horizon.

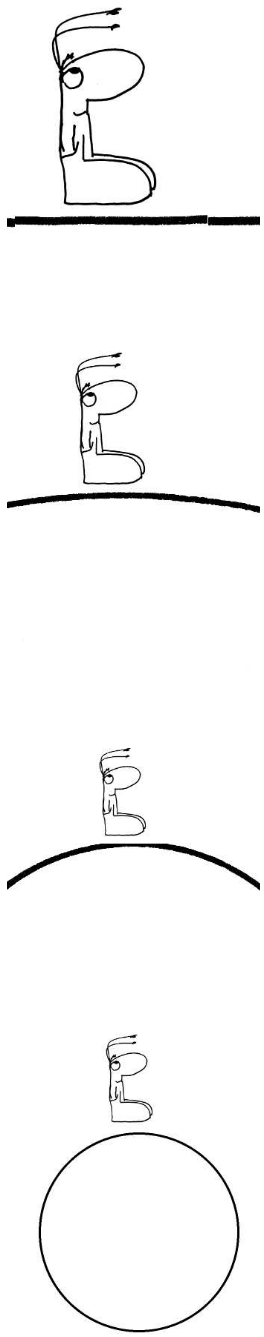

Figure 2. Every where you go, you're on top of the world. Even though the earth is curved, it is so large it appears to be flat.

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CA1 3.5: Moonrise and Moonset Activity

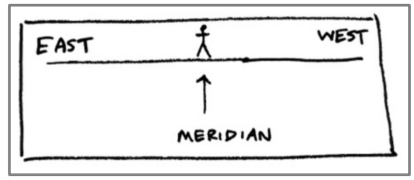

Figure 4. Horizon paper labeled with cardinal directions (East and West) plus the meridian (straight up). Cut this out and use it if you like.

Now label your horizon paper as in figure 4. You now have a tool you can use to tell the approximate position of the sun at any given time. The *meridian* arrow points to an imaginary line which runs from north to south. The picture is drawn as if you are facing south.

Part Two: Predicting moonrise and moonset.

There are three things involved in this prediction.

- The phase of the moon
- The local time
- The position of the moon above the horizon

If you know any two of these, you can use the horizon paper and a diagram of moon phases to predict the third.
First, you'll need to combine Figure 1 from this diagram with your finished moon phase diagram from CA1 3.3. Draw this below. Next, using your horizon paper tool, align the arrow with the time of the observation, choose a phase of the moon and then use the East and West designations to tell where the moon is. (The arrow also represents objects which are due South in the Northern Hemisphere.)

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CA1 3.5: Moonrise and Moonset Activity

Use your horizon paper and phase diagram and answer the following questions.

1. The moon is waxing crescent and it is 6 PM. Where is it in the sky?

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2. The moon is full and it is 6 AM. Where is the moon in the sky?

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3. What time does a 1st quarter moon rise?

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4. What time is a 3rd quarter moon as high as it gets during the night?

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5. What time does the waxing gibbous moon set?

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6. What phase of the moon is it when the moon is due south at midnight?

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7. What phase of the moon is it when the moon is visible rising in the east at 9 AM?

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CA1 3.6: Moon Phase and Eclipse Homework Handout

1. Without using a model, predict what an astronaut standing on the waxing crescent moon would see when she looked at the earth. What would the phase of the earth be?

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2. The moon takes roughly 28 days to complete a cycle of phases. About how long does it take to change from...

a. first quarter to full?

b. waxing crescent to 3rd quarter?

c. new to full?

d. first quarter to new?

3. Why do they call it first quarter moon when it only appears to be half-lit?

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4. What is the phase of the moon during a lunar eclipse?

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5. What is the phase of the moon during a solar eclipse?

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6. When people draw the moon as seen from above the earth's north pole, are they trying to indicate its position or its appearance?

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Print Name ______________________________ Period _________ Date ________________

CA1 3.6: Moon Phase and Eclipse Homework Handout

7. What is the phase of the moon when you cannot see the dark side?

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8. What is the phase of the moon when you can see half of the dark side?

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9. What makes eclipses of the sun as seen from the earth unique?

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10. Why do lunar eclipses last longer than solar eclipses?

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11. If you were living on the moon for a long time, how long would the sun stay up during the day?

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12. If you were on the moon watching the earth, would it rise or set?

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