6.1 KINESTHETIC MOON MODEL (KMM)

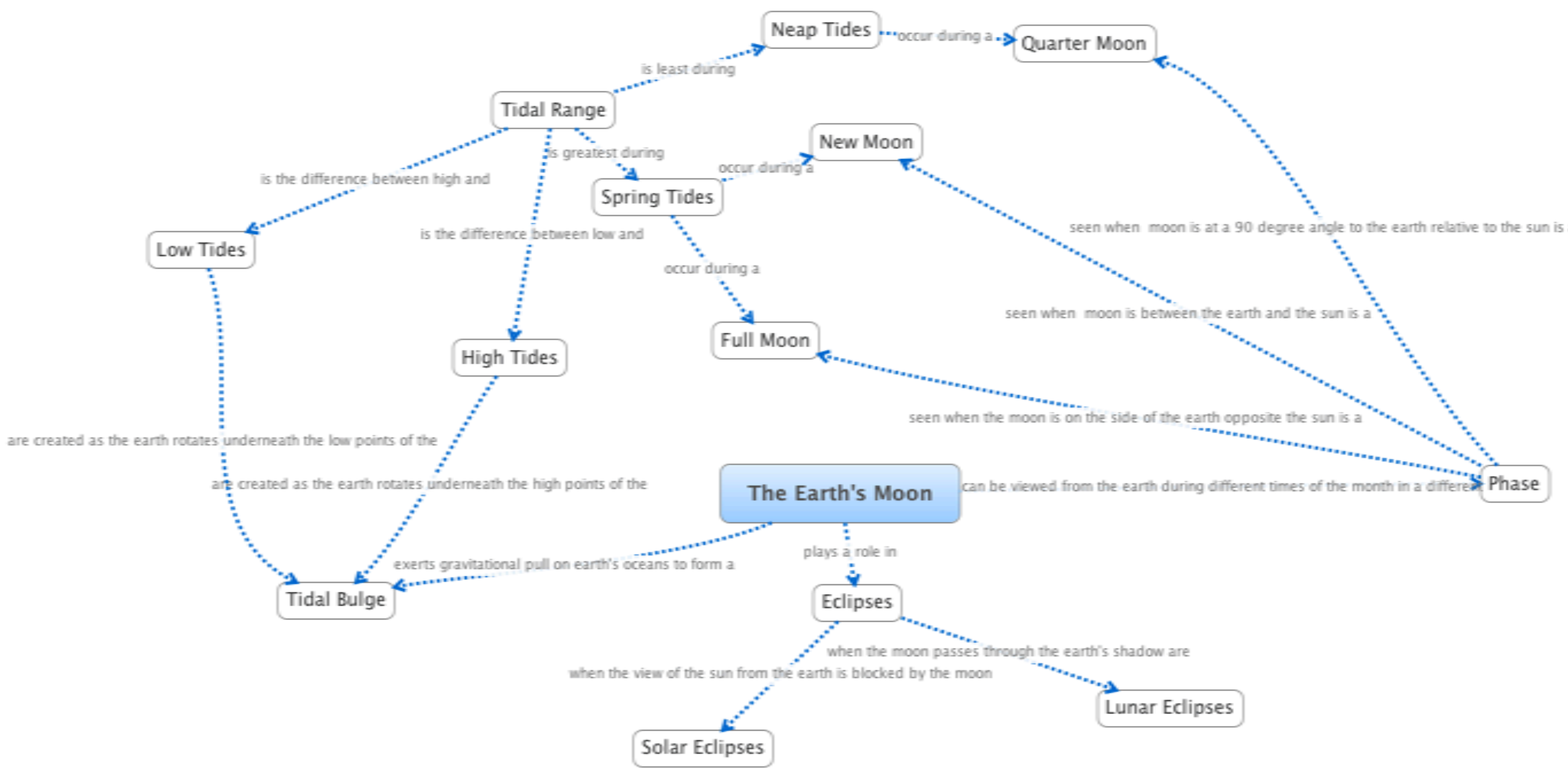

Image by Lauren Kaupp

T-KMM Fig. 6.1. Kinesthetic Moon Model concept map showing the relationship between Earth's moon and Earth's tides

Goals

Students will:

1. Model the movements of three objects in our solar system, the sun, moon, and Earth
2. Relate the movements of celestial bodies to tides on earth

Background and Introduction

Tidal movements affect the physics, chemistry, and biology of the ocean, as well as many human activities, such as boating and fishing. There is a large variation in tides between locations on earth. Tidal ranges are affected by factors ranging from coastal topography to the sun's gravity, but the moon is the principal cause of ocean tides on earth.

The rotation of the moon around the earth causes tides. The rotation of the moon about the earth is also the cause of several other natural phenomena, such as the phases of the moon, the dark side of the moon, and eclipses. It is important to clarify difference between these phenomena since misconceptions about the moon are common (T-KMM Table 6.2).

Orbit of the Moon

The moon completes a full elliptical orbit around the earth every 27.2 days. The moon's orbit around the earth is not in the same plane as the earth's orbit around the sun. In T-KMM Fig. 6.2 below, the blue sphere is the earth and the gray sphere is the moon.

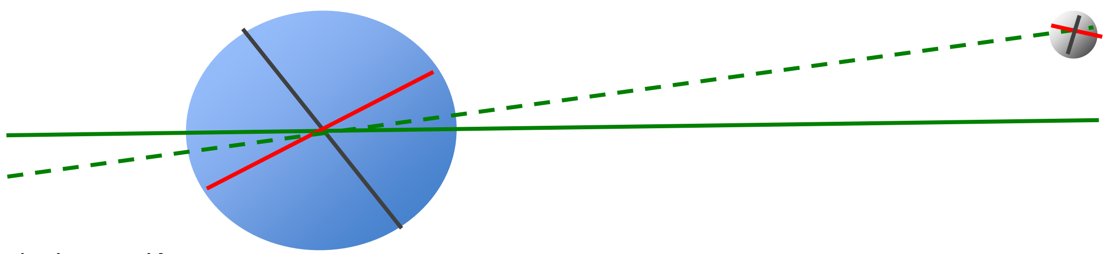

Image by Lauren Kaupp

T-KMM Fig. 6.2. This diagram shows the planes of orbit of the moon around the earth (dashed green line) and the earth around the sun (solid green line). The black lines represents the axis on both the moon and sun, the red lines represents the equator

Due to the gravitational effects of the earth on the moon, the moon and earth are tidally locked. This means the moon rotates around its axis in approximately the same time it takes for the moon to revolve around the earth. Because of this, the same side of the moon always faces the earth. This is called the near side of the moon. The side of the moon that always faces away from the earth is called the far side of the moon (see special feature on *Weird Science: Tidal Locking—Why the Man in the Moon Can Always See You*).

Phases of the Moon

Although it takes 27.2 days for the moon to orbit around the earth, we see a full moon every 29.5 days. Phases of the moon are caused by illumination of the moon by the sun. We see different phases of the moon based on our viewing angle of the moon, *not* due to shadows of the earth being cast on the moon. The sun always illuminates half of the moon. The phase of the moon we see is relative to the position of the moon's orbit around the earth (T-KMM Fig. 6.4).

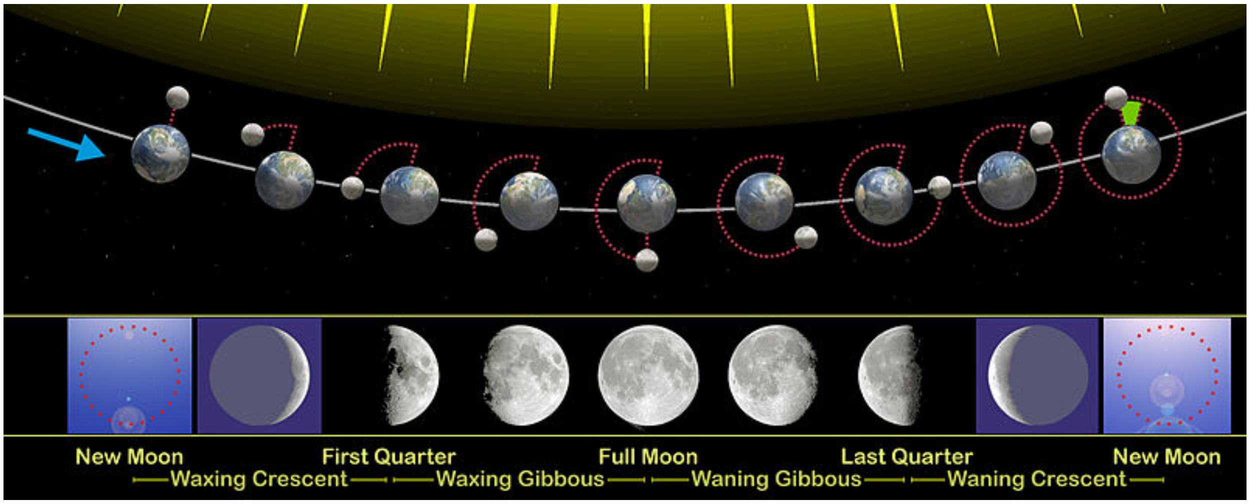

Image courtesy of Orion 8, Wikipedia Commons
http://en.wikipedia.org/wiki/Lunar_phase
T-KMM Fig. 6.4. The phases of the moon that we observe from earth are due to the portion of the moon that is illuminated by the sun that we are able to see.

Due to the brightness of the sun, it is easiest to see the moon at night, when you are facing away from the sun (although you can often see the moon during daylight hours as well). Imagine you are standing on the red star in T-KMM Fig. 6.5. The phase of the moon you see depends on where the moon is in its orbit. If the moon is at position I, you will see a full moon because the side of the moon that is illuminated by the sun is facing you on your side of the earth. If the moon is at position II or IV, you will see a quarter moon, because the side of the moon that is illuminate by the sun is only partially in your view. If the moon is at position III, there will be a new moon, because the side of the moon illuminated by the sun is facing away from the earth (and it is on the opposite side of the earth from the night sky).

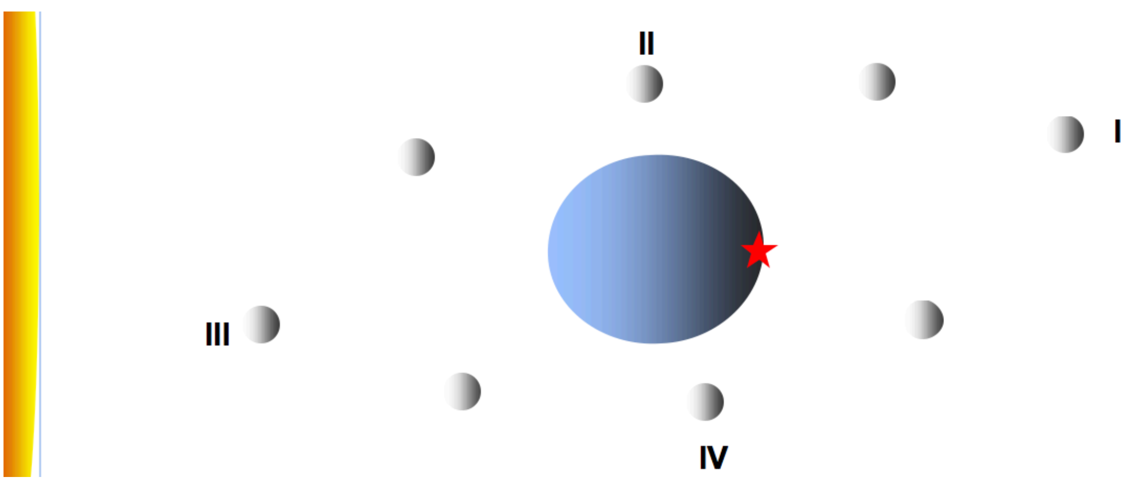

Image by Lauren Kaupp
T-KMM Fig. 6.5. Position of the moon relative to the earth and sun

<u>Tides</u>

The gravitational pull of the moon has the greatest effect on tides on earth. In T-KMM Fig. 6.6, the black line is the axis of the earth and you are standing at the red star. The moon pulls the water on the side of the earth that it is facing to create a bulge of water, or high tide where you are standing. There is also a bulge on the opposite side of the earth. This bulge is due to the difference in the gravitational force of the moon from one side of the earth to the other (i.e., the moon's gravitational pull is slightly stronger on the side facing the moon compared to the side facing away from the moon). The differences in these forces cause the ocean to elongate and form bulges on both sides of the earth. Now imagine that the earth is rotating about its axis. In 24 hours, the moon does not move very much in its orbit around the earth, so the position in space of the high and low tide change very little. As you stand on the red star, over a 24-hour period, you will rotate through two high tides and two low tides. Each day, the moon moves slightly in its orbit, so the times of the high and low tides change slightly.

Image by Lauren Kaupp
T-KMM Fig. 6.6. Tidal bulges on both sides of the earth. The black line is the earth's axis.

Although tides are mostly affected by the gravitational pull of the moon, the gravitational pull of the sun also plays a role. The gravitational pull of the sun on the earth can either reinforce or cancel out the pull of the moon. The sun, the moon, and the earth are in a line (although not necessarily in the same plane) at new moon and full moon (Positions I and III in T-KMM Fig. 6.5). During these times, twice a month, the sun's gravitational pull reinforces the moon's gravitational pull. These are called spring tides, because the tides are maximized, they "spring" up and down. When the moon is at a quarter moon, it is at a 90° angle to the earth/sun (Positions II and IV in T-KMM Fig. 6.5). In this position, twice a month, the sun's pull cancels out part of the moon's pull, resulting in neap tides, which have less extreme tidal ranges.

Just as the moon's orbit around the earth is elliptical, the earth's orbit around the sun is slightly elliptical. Although the ellipse of the earth's orbit around the sun is closer to a circle than the orbit of the moon around the earth, the small difference is distance from the sun has an impact on the tides. When the earth is closest to the sun (perihelion), the sun's effect on tides is greatest. When the earth is farthest from the sun (apihelion), the sun's effect on tides is weakest.

Eclipses

On earth, there are two types of eclipses, solar and lunar. Both occur when the earth, sun, and moon are in line and in the same plane. In a solar eclipse, the moon passes directly between the earth and the sun, partially blocking the view of the sun on earth. In a lunar eclipse, the earth passes directly between the sun and the moon, partially blocking the light from the sun that is reflected off of the moon.

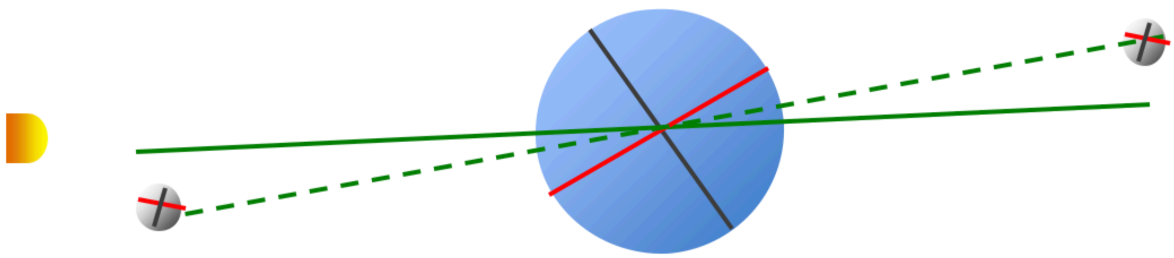

Image by Lauren Kaupp

T-KMM Fig. 6.8. The angle between the orbits of the moon around the earth and the earth around the sun is the reason that eclipses are relatively rare.

Phases of the moon are caused by the position of the moon in its orbit around the earth. Spring tides are caused when the sun, earth, and moon are all in line. These two phenomena can lead to confusion as to why eclipses do not happen every month. The key to understanding why eclipses do not happen every month is understanding that the orbit of the moon around the earth is not in the same plane as the orbit of the earth around the sun (T-KMM Fig. 6.8). An eclipse can only occur when the two orbits cross paths and the moon, sun, and earth are directly in line. During spring tides, the earth, moon, and sun are in line, but not in the same plane. Most of the time during a full moon or new moon, the moon is actually above or below the earth/sun plane. Even though the sun is much larger than the earth or moon, it appears in the sky as roughly the same size as the moon because it is so much farther away from the earth. This means that even the small angle between the two planes of orbit makes eclipses relatively rare. There are generally about 0 to 3 lunar eclipse per year and 2 to 5 solar eclipses annually.

T-KMM Table 6.2. Moon misconceptions

Misconception	Explanation
Moon Phases The moon's phases are caused by shadows of the earth, the sun, or clouds	The phases of the moon are caused by the movement of the moon, which is lit by the sun, around the earth. As the moon orbits Earth we see different amounts of the lit side of the moon. Earth's shadow does not affect the moon phases, but it does cause lunar eclipses. Lunar eclipses are rare because the sun, moon, and earth are rarely exactly aligned.
Dark Side of Moon There is a side of the moon that is always dark, the "dark side of the moon"	From Earth, we always see the same side of the moon because the same side of the moon constantly faces Earth. This can lead to the idea that only one side of the moon is ever lit by the sun. However, just as one half of Earth is always dark and one half is always light, one half of the moon is always lit and one half is always dark. The side of the moon that is lit is not always the same half. As the moon rotates, the half that is lit also rotates.
Visibility The moon is only visible at night	The moon is in the day sky just as often as it is in the night sky. However, it is much easier to see the moon at night when the sun does not obscure the presence of the moon and stars.
Moonlight The moon emits its own light or the moon is very reflective.	The moon reflects the sun's light; it does not emit its own light. The moon's surface is not very reflective (about as reflective as asphalt), so most sunlight is absorbed by the lunar surface. The moon appears bright because it stands out against an even darker sky.
Gravity The moon does not have gravity	Any object that possesses mass (matter) has the force of gravity. Because the moon has less mass than Earth, it has less gravitational force. The moon's gravity is about 1/6 of that on Earth.
Rotation The moon does not rotate	The moon completes exactly one rotation about its axis in the same period of time it takes to make one revolution around the earth. That is why we always observe the same hemisphere of the moon facing us.
Tides If the earth had no moon, there would be no tides.	Tides are caused by the gravitation pull of both the moon and the sun. If the earth had no moon, there would still be (smaller) tides caused by the sun.

Additional misconceptions and confusions:

- Confusion between eclipses and moon phases.

Activity: Kinesthetic Moon Model

T-KMM Table 6.3. Suggested activity time, if adhering closely to activity as written with no major modifications, assuming class periods of 40 minutes.

	Minutes	**Task**
Outside of Class	20	Prep supplies and room
	10	Clean up
Day 1	10	Introduction to activity Move desks if necessary
	30	Activity
Day 2	15	Recap activity
	25	Assign activity questions for homework or discuss in class

T-KMM Table 6.4. Materials, if adhering closely to activity as written with no major modifications, assuming class of 32 students

Materials	Quantity	Per	Class Total	Notes on Material Number or Material Modification
Styrofoam “moon” ball	1	Student	32	Use the smooth (not crumbly) type of Styrofoam because it is more reflective
Pencil	1	Student	32	Pencils should be sharpened; can also use skewer or chopstick.
Light bulb “sun”	1	Class	1	Use bulb with a high wattage Hang the light (in utility light holder) in the center of the classroom. It must be unobstructed/uncovered when hanging. If possible, the bulb should hang at approximately eye level for most students.
Portable utility light	1	Class	1	May of these lights comes with “cages” around the bulb that are removable. Remove the cage to eliminate shadow. You may need an extension cord.
Materials to darken room	Varies	Class	Varies	This activity is more effective when room is reasonably dark. Windows can be covered with black trash bags, blankets, etc.
Picture of familiar geographic area	1	Student	32	Small map of geographic area familiar to students, e.g. their country or state.
Sticker	1	Student	32	Small sticker, e.g. “star” stickers.

Materials Details
*Picture of familiar geographic area

- Picture should be about the size of a human forehead.
- Picture should have east and west is clearly labeled. When held up to the students' forehead or chest, west should point to the right arm and east should point to the left arm.

Procedural Modifications
These procedure modifications may affect timing of the activity and/or supplies. Other modifications are listed in next section, the teacher version of the procedure.

- Only go through as many parts as you need to in order to cover your class goals.
- Work through the activity over a longer time period by just doing one or two parts a day.

Planning with TSI

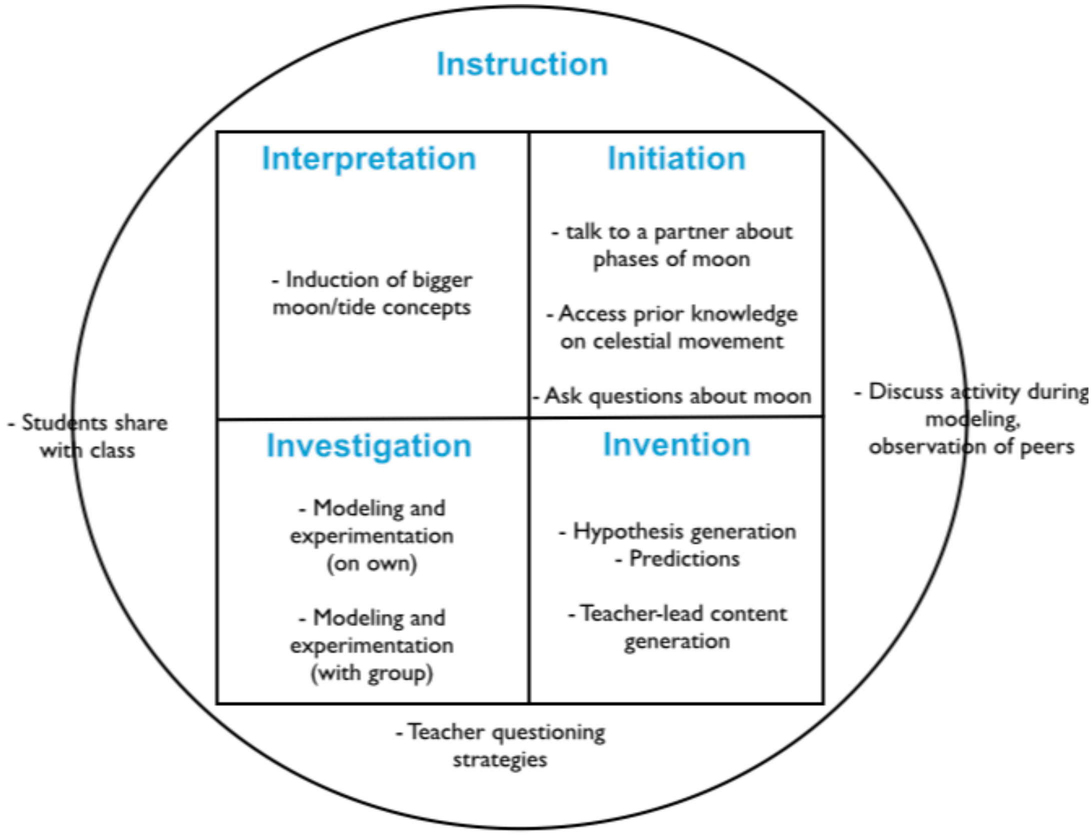

Image by Joanna Philippoff
T-DB Fig. 6.9. Planning *Kinesthetic Moon Model Activity* through TSI phases

Focus Modes(s):

- Authoritative Knowledge
  - Although the activity is guided by the instructor, students constantly test their hypotheses through movement.
- Replication
  - Students test their own ideas, then work in groups to come to consensuses
- Induction
  - Repeatedly observing movements of the moon and the earth in relation to the sun will lead to generalizations about how the location and rotation of these celestial objects causes phenomenon like the phases of the moon and eclipses.
- Description
  - Students demonstrate movements of the earth, moon, and sun and learn new terminology to describe the cause and effects of these motions.

Procedure

This is a teacher-led and highly interactive activity. The procedure below is a suggested progression through several topics. The text in **black** is designed to be read aloud to your students. The text in **blue** are notes on how to facilitate this activity.

Make sure that the room is safe for students to move freely. Desks may need to be pushed to the center or side of room if possible.

Part A—Introduction

1. Why does the moon have phases? Write your thoughts in your notebook.

2. Share your thoughts with your partner or group.

At this point, it is not necessary to correct misconceptions.

3. How could we test our ideas about moon phases?

Discuss use of models in science. We cannot go to space to observe the moon phases from afar. Students may suggest physical models, computer models, etc.

Part B—Day and Night

Darken the classroom as much as possible.

1. In this model, the bulb represents the sun and you represent the earth. The top of your head is the North Pole. Imagine a tiny person standing on Mt. Nose (your nose). When is that person going to experience day and night?

Allow students to experiment.

2. Everyone face the sun. If the sun is beaming directly on your nose what time is it?

Noon.

3. Where must you face for Mt. Nose to experience midnight?

Turn 180 degrees from previous position.

4. When Mt. Nose experiences midnight, what is happening on the back of your head? Either ear?

The back of your head is experiencing noon. One ear is experiencing morning and the other ear is experiencing evening.

5. Which direction does the earth rotate? Think about where the sun rises and sets on Mt. Nose.

This question is more difficult to visualize. The sun rises in the east and sets in the west. In the model, you are initially facing out toward space. If it helps, imagine a map of the US on your face, where Mt. Nose is in the middle. On your face, east (Atlantic ocean side) is on your left and west (Pacific ocean side) is on your right. That means that the earth must turn counterclockwise for the sun to rise in the east and set in the west. Ask students to try this a few times.

It may help to print out a small map of your country or state for students to mark directions and then hold up to their faces. (Note that if holding a map to their face makes students uncomfortable, they can hold the map to their body, however they will need to keep their head aligned to their body to accurately observe the rotation of the Earth.)

6. How long does it take the earth to make one full rotation?

24 hours

Part C—Moon Phases

Distribute moon balls to each student. If you have never completed this activity before, you may have the first group assemble the moon balls.

1. You head is still the earth and you are now holding the earth's moon. Hold the moon at arm's length away from your head. Take five minutes to attempt to model the phases of the moon.

Circulate the room to encourage students to stay on task, but do not correct misconceptions yet.

2. Did anyone recreate moon phases? Find a partner and discuss what you did to achieve moon phases.

Allow students to discuss.

3. What causes the moon to be visible in the sky?

Light from the sun is reflected off of the moon. The moon does not produce its own light.

4. Everyone face Mt. Nose towards the sun. Hold the moon in your right hand and hold your arm straight out in front of you. Turn to your left (counterclockwise) until you see a sliver of light on your moon. How much of your moon is lit by the sun?

Half of the moon.

You may also ask students to look at other student's moons and again ask, how much of everyone's moon is lit by the sun?

5. What percentage of the lit portion of your moon can you see?

Only a small percentage (answers will vary). This is called a crescent moon.

6. Slowly turn to your left until your head, moon, and the sun form a right angle. How much of your moon is lit by the sun?

Half of the moon.

7. How much, or what percentage, of the lit portion of your moon can you see?

You can see half of the lit side of the moon (50%), which means you can see 25% of the moon. This is called a quarter moon. Because the amount of the lit moon we can see is increasing, we say the moon is *waxing*.

8. Continue to slowly turn left until you can see about ¾, or 75%, of the lit portion of the moon. How much of your moon is lit by the sun?

Half of the moon is still lit by the sun (remember this does not change), but you can see about 37% of the moon now.

9. What do you predict we will observe if we continue to turn left until your moon, the earth (your head), and the sun are in a line? Why?

When the moon, the sun, and the earth are lined up we should see all of the lit side of the moon (100% of the lit surface of the moon lit by the sun, which is 50% of the whole moon). This is called a full moon.

10. Let's see if our prediction is correct. Make a model of the moon, the sun and the earth in a line.

Students holding their moon directly in front of them will not see a full moon as their head will block the moon.

11. What must you do to observe a full moon?

To observe a full moon, your moon has to be slightly above your head; otherwise your head blocks the light of the sun. Ask everyone to hold their moon a little over their heads to see the full moon.

12. About how often do we see a full moon? (Think about how long it takes for the moon to orbit the earth).

You see a full moon (on average) once a month. It takes about 28 days for the moon to orbit once around the earth.

13. If full moons are relatively common, and we had to hold up our moon ball above our heads to see a full moon, what does this tell us about how the moon orbits the earth?

This tells you that the orbits of the moon and the earth are not exactly in line.

14. Continue to hold your moon slightly above your head and slowly rotate your moon to the left side of the room until you see another quarter moon. What is happening to the percentage of the moon that you can see?

The percentage of the moon you can see is decreasing. This is called *waning*.

15. Is the percentage of the moon that is lit decreasing?

No. The sun always lights half the moon, but we see less of that lit half.

16. What do you predict we will observe if we continue to rotate towards the left until your moon is between the earth (your head) and sun? Why?

The percentage of the lit side of the moon we can see is decreasing. When the moon is between the earth and sun, the lit side of the moon will be facing away from the earth, so we will not be able to see any of the lit moon.

17. Let's see if our prediction is correct. Model the moon between the sun and the earth. Remember to keep your moon up.

Students who have dropped their arm and are not longer holding their moons slightly above their heads will see a solar eclipse. Remind students to keep their moons up.

This is called a new moon, because you cannot see the moon (in our model the new moon can be seen but is completely dark).

18. What portion of the moon is lit by the sun? Why?

Half of the moon is always lit by the sun, because half of the moon is always facing the sun.

19. Why can't we always see the lit portion of the moon?

The position of the moon relative to the earth affects the amount of the lit portion we can see.

20. What causes the phases of the moon?

Phases of the moon are caused by the location of the moon relative to the earth. Depending on where the moon is relative to the earth, we can only see part of the lit portion of the moon in the sky.

Part D—Observing Eclipses

1. When we modeled a full moon, we had to hold our moon balls away from our heads and learned that the moon, the earth and the sun were not exactly in line. What happened if you did not move your moon ball slightly above your head? Let's model this by keeping the moon in line with your Earth head.

Instead of a full moon Earth's shadow blocks the sunlight and you moon is not lit at all.

2. Does anyone know what this is called?

This is called a lunar eclipse.

3. Why is there not a lunar eclipse every month?

This should reinforce what they discovered previously about the moon not being in line with the earth in order to see a full moon.

4. What happens if you hold your moon ball slightly below your head?

Your body blocks the sunlight. In our model, we have to hold the moon above our heads. But the real earth does not have a body to block sunlight, so a full moon can be seen if the moon is both above and below the plane of the sun and the earth.

5. Recreate a new moon. Where does your moon have to be positioned for you to see a new moon?

The moon cannot be directly in line with the earth, but it can be slightly above or below your head.

6. What happens if your moon passes directly between the sun and the earth (your head)?

The moon blocks out much of the sun's light. This is called a solar eclipse.

7. Model a solar eclipse.

Students will have to hold out their moon balls directly in front of them and close one eye.

8. Look around the room without moving. How much of everyone's face is covered by their moon's shadow?

The moon's shadow will just cover one eye.

9. Is everyone's nose, chin, or lips witnessing a solar eclipse?

No. The moon's shadow only covers a small portion of the earth.

10. Why is there not a solar or lunar eclipse every month?

The moon is not always in a direct line with the sun and the earth. This is because the orbit of the moon is at an angle relative to the orbit of the earth around the sun. However, this orbit is not fixed and on rare occasions, when the orbit of the moon crosses the orbit of the earth close to the full moon or new moon, an eclipse can occur.

11. Based on what we saw of how much of the earth was covered by the moon's shadow during a solar eclipse, and what you know of the difference in size between the moon and the earth, what do you think you are more likely to observe– a lunar or solar eclipse?

Lunar eclipses. The moon's shadow on Earth is much smaller than the earth's shadow. Have students model this themselves.

Part E—Earth and Moon Rotation

1. How long does it take the earth to make one full rotation on its axis?

24 hours

2. How long does it take the moon to orbit around the earth?

Approximately 28 days

3. How much does the moon move in its orbit each Earth day (each Earth rotation)?

The moon moves 1/28 of its orbit

4. Try to model not only the rotation of Earth once a day but also the slower orbit of the moon compared to the earth.

Give students a couple of minutes to try this model.

5. What do you observe? What does this tell us about our model?

It is difficult to model the moon orbiting the earth and the earth rotating as one person. Sometimes we have to change our models to include new information or become more accurate.

For the rest of this activity, have students pair up, with one person acting as the earth and one acting as the moon. This makes the moon and the earth easier to model. Have students switch who is modeling the moon and who is modeling the earth so each student can see things from both perspectives.

Gives student pairs a couple of minutes to model the rotation of the earth and slower orbit of the moon.

6. We have now added the rotation of the earth and the slower orbit of the moon to our model. Does the moon rotate as well?

Answers will vary. Do not correct at this time.

7. Do we always see the same side of the moon?

Yes. Students may have heard of the man in the moon. This stems from some people thinking the dark areas on the moon looked like a man's face. No matter how much of the lit moon we can see, we always see the same side of the moon.

8. If we always see the same side of the moon, does that mean the moon rotates or does not rotate?

Give students a couple of minutes to try to model this in pairs. Students can put stickers on their moon balls as reference points.

9. In your pairs, have one person model the earth and hold a moon. The second person should stand in outer space and look at the moon. The person modeling the earth and moon should keep the same side of the moon facing them and rotate (stickers may help with this as a reference point). What do the people modeling the earth see? Does the moon appear to rotate?

To the "Earth", the moon may not appear to rotate. They will always see the sticker. Do not address this misconception yet.

10. What do the people in "outer space" see? Does the moon appear to rotate?

Students in "outer space" will see that to keep the same side of the moon facing "Earth", the moon has to rotate, but slowly.

Have students in pairs switch roles so each person can see the moon from Earth and from space.

11. How long does it take the moon to rotate around its axis?

The moon completes exactly one rotation around its axis in the same period of time it takes to make one revolution around the earth. That is why we always observe the same hemisphere of the moon facing us.

12. We often hear that the moon has a "dark side", a side of the moon that is always dark. Do you think this is true?

Give students a couple a minutes to model this with their partners. One half of the moon is always lit and one half is always dark. However, it is not always the same half. As the moon rotates, the half that is lit also rotates.

Part F—Moon Visibility

1. For the next part of the activity, think about time being where Mt. Nose is as Earth rotates. Let's model this. When you are directly facing the sun, it is noon on Mt. Nose. When the sun is directly on your back, it is midnight on Mt. Nose. Model the position of the earth when it is:

- 6 am on Mt. Nose
- 9 am on Mt. Nose
- 3 pm on Mt. Nose
- 6 pm on Mt. Nose

- 9 pm on Mt. Nose
- 3 am on Mt. Nose

It may help to have students modeling the earth to stand on a large piece of paper taped to the floor with times clearly marked for when they face different locations. It may also help to use a 24 hour clock.

2. Let's model midnight on Mt. Nose. Then, slowly rotate until it is sunrise on Mt. Nose. This is when you can first see the sun. You may move your eyes left and right while keeping your head steady. Remember that time is dictated by the position of Mt. Nose. When it is sunrise, about what time is it on Mt. Nose?

About 6 am

3. When it is sunset, about what time is it on Mt. Nose?

About 6 pm

4. The sun rises and sets based on when we can first and last see it. Does the moon rise and set as well?

Yes. When you can first see the moon is called the moonrise (just like sunrise). When you can last see the moon is called moonset.

5. Working with a partner (one person is the earth, one is the moon), model a waxing quarter moon. What time does a waxing quarter moon rise and set? Model this by seeing what time the rotating earth can first see a waxing quarter moon. Remember, time is on Mt. Nose, but your eyes can move if you keep your head steady.

The person modeling the earth can rotate (counterclockwise) and see when they can see the moon rise (about noon) and when they can see the moon set (about midnight).

6. Can you see a quarter moon during daylight hours on Mt. Nose?

Yes.

7. Choose a different phase, for example a waning crescent moon. When can the rotating earth first see the moon? When can they last see the moon?

Give time for students to model moonrises and sets. Answers will vary. For the waxing crescent moon, the moon will rise in early morning and set in early afternoon.

8. Can you see a full moon during the day?

Have students model this phase to answer the question. You cannot see a full moon during mid-day, but you may see the full moon at dawn and dusk.

9. What time does a full moon rise and set?

At sunset the moon rises (~6pm) and at sunrise the moon sets (~6am).

10. Can you generalize about what times different phases of the moon rise and set?

The closer the moon is to full or new moon phase, the closer its rise and set times are to dawn and dusk. The other phases of the moon rise and set at different times of the day depending on how much of the lit moon you can see.

Half of the moon's orbit, and thus phases, are during the earth's daytime. Half are at night.

11. Do you see the moon during the daytime?

The brightness of the sun usually overwhelms the light of the sun that is reflecting off of the moon. However, we sometimes are able to see the moon in the day, and can often see it at dawn and dusk.

Part G—Solar System Model

1. We have addressed both the earth and moon rotation in our model. How else might our model be misleading? (For example, think about the movement of earth).

The earth does not remain in the same position in space while it rotates. It orbits around the sun.

At this point, if it hasn't come up already, it is also important to bring up that this model is not to scale. If your students are struggling with celestial size and distance misconceptions you may want to create a scale-size solar model.

2. How long does it take the earth to orbit the sun?

One year or 365 days

If you have the space, have students try to model this complex interaction of the sun, the moon, and the earth.

Part H—Gravity

Gravity is the cause of the orbits of the earth around the sun and the moon around the earth. The earth and moon are constantly pulling on each other due to gravity. What other effects might the pull of the moon have on the earth and vice versa?

One effect is tides. The movements of the moon, sun, and earth cause tides. If students do not come up with tides at this point, you may ask further probing questions, such as "Do any other natural phenomena occur on regular cycles?"

Answers to Questions

1. Explain the movement of the moon in relation to the earth over the course of:
   a. 24 hours
   The moon completes 1/28 of its orbit around the earth.

   b. a month
   The moon completes one full orbit around the earth.

   c. a year.
   The moon completes 12 full orbits around the earth.

2. Explain the movement of the earth in relation to the sun over the course of:
   a. 24 hours
   The earth makes one full rotation. It completes 1/365 of its orbit around the sun.

   b. a month
   The earth makes at least 28 full rotations. It completes 1/12 of its orbit around the sun.

   c. a year.
   The earth makes 365 full rotations. It completes one full orbit around the sun.

3. Draw the relative positions of the sun, the earth, and the moon during a:
   a. new moon
   The moon should be between the sun and the earth.

   b. first quarter moon (Fig. 6.4 A)
   The moon, the earth, and the sun should be at right angles. When viewed from the North Pole in space, the moon should be to the left of the earth.

   c. full moon (Fig. 6.4 B)
   The moon earth should be between the moon and sun.

   d. third quarter moon (Fig. 6.4 C)
   The moon, the earth, and the sun should be at right angles. When viewed from the North Pole in space, the moon should be to the right of the earth.

4. Compare your observations with the solar system model to the real world. What does the model represent accurately? What does the model not represent accurately??

   The model can show the moon orbiting the earth, but it is difficult to show this happening while the earth is rotating on its axis and orbiting around the sun. It is also difficult to show how the moon rises and sets. The model shows day and night, moon phases, and eclipses well. It does not show the moon's rotation, seasons, or accurate timing well.

Further Investigations: Tidal Movements

1. Observe the moon every night at the same time for an entire month.
   a. Draw and record your observations on a calendar.
   b. Compare your observations of the moon to a tide calendar. How do your observations of the moon compare to the tides on the calendar?

   Tidal movements are greatest when the sun, the moon, and the earth as aligned. Tidal movements are smallest when the sun, the moon, and the earth are at right angles.

2. Research how tidal movements affect daily life for people that live in coastal communities (e.g., school, shopping, recreational activities, etc.).

   Tidal movements affect various geographical areas differently. Areas with large tidal fluctuations are more affected by tidal movement than those with smaller tidal fluctuations.

3. Why are full moons so common while lunar eclipses are relatively rare? Describe or draw the relative positions of the earth, the sun and the moon during the following events:
   a. full moon
   b. lunar eclipse
   c. new moon
   d. solar eclipse

   See the special feature Weird Science: Eclipses *to answer this question.*