INTRODUCTORY ACTIVITIES

KWL CHART

Use the KWL chart to begin a discussion about the core activities for any of the following questions:

- What kinds of objects orbit/operate above Earth's surface?
- How far away from Earth's surface does the International Space Station orbit?
- How far away is the Moon?
- At what altitudes do airplanes and satellites fly?
- What do you know about the layers of the atmosphere?

K What do you **know**?	**W** What do you **want** to learn?	**L** What did you you **learn**?

BALL AND STRING EARTH-MOON MODEL ACTIVITY

Description

Determine how far away the model Moon and International Space Station are from a playground ball used to represent Earth. Unwrap a string to show the scaled distances. Students make their own models based either on a ball's circumference or on its diameter.

Objectives

Students will

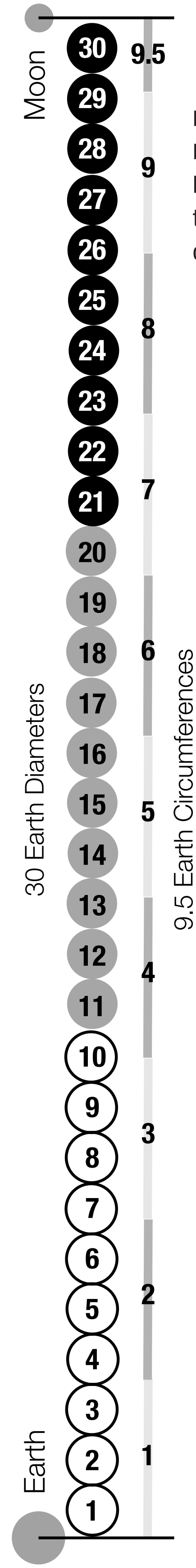
- predict the distances of the Moon and the International Space Station from a model Earth,
- create appropriate scales to make models of the Earth-Moon system using a ball's circumference or diameter, and
- explain how a model helps them understand distances.

Materials

- ☐ Inflatable ball (~75 cm in circumference)
- ☐ Tennis ball
- ☐ Balls of assorted sizes (1 per pair of students)
- ☐ Modeling clay (1 piece per pair of students, optional)
- ☐ String (1 per pair of students)
- ☐ Markers (1 per pair of students)
- ☐ Rulers (1 per pair of students)
- ☐ Earth-Moon Model Worksheet (1 per student)
- ☐ Calculators (1 per pair of students)
- ☐ Small plastic beads (optional)

Background

Students usually do not know how far the Moon or the International Space Station is from Earth. This activity will give you insight into your students' thinking and begin to show them the power of using models to make sense of distances.



Ball and String Earth-Moon Model: The Earth-Moon distance is 9.5 times Earth's circumference, or 30 times Earth's diameter.

Preparation

- Go to a discount store to find an inexpensive supply of balls of different sizes, or have students bring in some. Try inflatable balls, marbles, tennis balls, golf balls, table tennis balls, softballs, superballs, plastic toy balls, basketballs, soccer balls, volleyballs, etc. You will need one ball per pair of students.

- Make sure you have an inflatable ball or a playground ball with a circumference of about 75 cm. With a model Earth this size, you can use a tennis ball to represent the Moon (about 7 cm in diameter).

- Tape one end of the string to the ball.

- Measure the string to represent the Earth-Moon distance to scale. To use circumference as a unit of measure, wrap the string 9.5 times around the ball. To use the ball's diameter as the unit, measure 30 times the ball's diameter (diameter = circumference / π).

- Note the beginning point where the string is taped to the ball. As you wrap the string around the ball, mark the string each time you come to the beginning point. This way you know each wrap is one circumference of the ball.

- Color every other circumference length with a marker. This will help students see nine-and-a-half circumference units.

- On this scale, you can represent the height of the International Space Station at a typical orbit by coloring a segment of the string 1 cm from the ball's surface. Below this point are the three lower layers of the atmosphere.

- For a complete mathematical explanation about calculating the model Earth-Moon string length, see the teacher note at the end of the activity on page 19.

Procedure

1. Hold up a ball to represent the size of Earth. If a ball with a circumference of 75 cm represents Earth, a tennis ball represents the Moon.

2. Ask students to estimate how far they think the model Moon is from the model Earth. You may want to suggest a few distances to get a discussion started, such as 15 cm (~ 6 in), 30 cm (~ 1 ft), 60 cm (~ 2 ft), 1 meter (~ 3 ft), 2 meters (~ 6.5 ft).

3. Ask them to estimate how far away from Earth the International Space Station orbits with this model.

4. Ask how they could find out how far away the Moon (tennis ball) is from the Earth (ball). Consider encouraging them to research the answer instead of just spoon-feeding them.

5. The Moon orbits Earth at a distance of 384,430 km. Does that number mean anything to them? How far away is that?

6. Discuss why it's helpful to use models.

   - make big numbers smaller, more human-sized;
   - break the distance into parts;
   - examine the smaller parts more closely; and
   - compare the unfamiliar to the familiar.

   More information on models appears on page 39, step 3, and on page 9, Science Standards, 1st bullet.

7. You'll need a volunteer to help you show the distance using the scaled model.

8. While you hold the ball, have the volunteer take the loose end of the string and begin to walk across the room. Rotate the ball to help unravel the string as the student walks, and walks, and walks! The distance is pretty dramatic. Ask who is surprised with the answer.

9. Explain the markings on the string as being distances that use units of either the model Earth's circumference or its diameter, depending on which method you choose. The Earth-Moon distance is about 9.5 times

Earth's circumference, or 30 times Earth's diameter. Do these units seem more meaningful than 384,430 km? Why is that?

10. Ask where the International Space Station orbits in this model. Point to the tiny segment of the string where the International Space Station orbits 1 cm above the surface of the ball. Isn't this amazingly close to Earth's surface? The real International Space Station orbits at around 400 km above the surface.

11. To put these distances into perspective, identify what and where the three lower layers of the atmosphere are: Troposphere, Stratosphere, and Mesosphere.

    The Troposphere is the one that contains our oxygen. The lower three layers of the atmosphere end halfway to the International Space Station. Surprise!

12. Have students complete the worksheet to build their own Earth-Moon models.

13. When students have completed their models, have them stand in order by the size of their models, from smallest to largest. Have them compare the size of their models and share observations about other models.

Discussion

1. What is a model? *A model is a replica or copy of something we want to study. It lets us explore things that are really big, really small, really far away, or really complex.*

2. How is a model like the real thing? *A model has some characteristics of the real thing. In the Ball and String model, the distance between Earth and the Moon is to scale.*

3. How is a model different from the real thing? *A model is not completely accurate because it is a copy of the real thing; it only has a few of the characteristics of the real object.*

4. How does a model help you understand the Earth-Moon distance? *It makes a big number more human-sized and breaks the distance into parts.*

5. Complete the following sentence: "One thing I was surprised to learn is. . . ." *Answers will vary.*

6. Complete the following sentence: "One thing I don't understand about making a model to scale is. . . ." *Answers will vary.*

7. Based on this activity, do you think you could make another Earth-Moon model given a different-sized ball? *Answers will vary.*

8. How do you find the scale of a model compared to the real thing? *Set up a ratio. (scale size):(real size)*

9. How do the different models compare in size? *The smaller the scale, the smaller the distance between the objects.*

Extensions

- Discuss the teacher facts on page 19 with students if appropriate.
- Calculate and make a scaled Earth-Moon model using toilet paper sheets as a method of measurement.
- Make a model using a huge Earth ball for parents' night, and have the string taped to the wall going down the hallway.

Name ______________________________

Teacher ______________________________

Period ______________________________

Date ______________________________

Earth-Moon Model Worksheet

Getting Ready

- For this activity, you will work with a partner to make a model of the Earth-Moon system to scale using a ball of any size.
- Have one partner get the first three materials in the list and the other get the last three items on the list.
- Choose the method you will use to find the scaled Earth-Moon distance: Earth's circumference or Earth's diameter. Be sure to follow that method below.

Materials

- ☐ 1 ball
- ☐ Modeling clay (optional)
- ☐ String
- ☐ Markers
- ☐ Ruler or meter stick
- ☐ Calculator

Begin

1. Wrap a string once around the ball. Mark the string carefully. Remove the string and measure it.

2. a. What is the circumference of the ball? ________________

   b. Circumference Method: The Earth-Moon distance is about 9.5 times the circumference of Earth.

   What length should the string be for your model? ________________

   or

3. a. What is the diameter of the ball (diameter = C / π)? ________________

   b. Diameter Method: The Earth-Moon distance is about 30 times Earth's diameter.

   What length should the string be for your model? ________________

4. Add an extra 2 cm to the length you calculated. This leaves room to tape the string to the ball. Cut the string to this new length.

5. Cover the extra 2 cm of string with tape and attach the string to the ball.

6. The circumference of Earth is 40,030 km. Determine the scale you will use to create the rest of your model, using this formula: Scale = C_{ball} / C_{Earth}

7. Find the scaled measurements for the following, using the scale from step 7.

Real Object	Actual Measurement (km)	Scaled Measurement (cm)
Moon's Radius	1,738	
International Space Station Orbital Altitude	400	

8. Make a Moon to scale using modeling clay, or find a ball close to the appropriate size. Place the model Moon at the end of the string to complete your model.

9. Use a red marker to color a dot on the string to mark the International Space Station's orbit.

Worksheet Answer Key

The following table contains measurements for a variety of balls that could be used in this activity. Approximate answers for the Earth-Moon Model Worksheet are included in the table. NOTE: Ball sizes may vary, so student responses are likely to vary as well. The chart below is designed to give "ballpark" answers. The important thing to remember is that the distance to the Moon is about 9.5 times Earth's circumference or 30 times Earth's diameter. The abbreviation for the International Space Station is ISS.

Ball	Ball Circumference (cm)	Ball Diameter (cm)	Scale (cm/km)	Scaled Distance to Moon (cm)	Scaled Moon Radius (cm)	Scaled ISS Altitude
3/8" Steel Shot	3.5	1.1	0.00009	34	0.2	0.0
Marble	5.5	1.8	0.0001	53	0.2	0.1
Marble Shooter	8.0	2.5	0.0002	77	0.3	0.1
Superball	8.5	2.7	0.0002	82	0.4	0.1
Table Tennis Ball	8.5	2.7	0.0002	82	0.4	0.1
Golf Ball	13.4	4.3	0.0003	129	0.6	0.1
Baseball	23.0	7.3	0.0006	221	1.0	0.2
Softball	30.5	9.7	0.0008	293	1.3	0.3
Inflatable Ball	74.5	23.7	0.002	716	3.2	0.7
Soccer Ball	70.0	22.3	0.002	673	3.0	0.7
Volleyball	65.0	20.7	0.002	625	2.8	0.6
Basketball	75.5	24.0	0.002	725	3.3	0.8

TEACHER FACTS: THE MATHEMATICS BEHIND THE BALL AND STRING MODEL

This note is meant to give further clarification for teachers interested in knowing precisely what factors affect how to create the model, and it introduces several discussion/research topics that you may want to use as an extension for this activity. While you and your students create your own model, keep in mind what you know and teach about the accuracy and precision of measurements, significant digits, and rounding.

Distances between planetary bodies are typically cited as being between the centers of each body. This needs to be taken into account when designing a scale Earth-Moon system using playground balls and string because it is not possible to start the string at the center of the ball. We will account for the radii of Earth and Moon when we connect the string to the surface of the ball. The exact scale for your model will depend on the size of the ball you use to represent Earth. Here's how to do it.

Start with an average inflatable ball from a retail store, a kickball, or basketball. Keep in mind that such balls tend to lose air over time and, once you have made your model, you should check the ball's circumference if you haven't used it in a while.

1. Use a piece of string to measure the circumference of the ball. From the circumference, determine the radius of the ball. Our ball's circumference is 74.5 cm.

   Circumference = $2\pi r$
   $\pi = 3.14$
   Therefore, $r = C / 2\pi$
   $C_{ball} = 74.5$ cm
   $r_{ball} = C_{ball} / (2\pi) = (74.5 \text{ cm}) / (2\pi) = 11.8$ cm

2. Determine the scale you will use to create the rest of your model.

   Scale = $C_{ball} / C_{Earth} = (74.5 \text{ cm}) / (40{,}030 \text{ km}) = 0.002$ cm/km

3. Determine the scale model radius of the Moon and check to make sure that your calculated ball radius matches the scaled radius of Earth.

   $r_{Moon} = 1{,}738$ km
   Scaled Moon radius $r_{SMoon} = (1{,}738 \text{ km}) * (0.002 \text{ cm/km}) = 3.5$ cm
   $r_{Earth} = 6{,}371$ km
   Scaled Earth radius $r_{SEarth} = (6{,}371 \text{ km}) * (0.002 \text{ cm/km}) = 12.7$ cm

   Why is the scaled Earth radius not the same as the radius of the ball? This is because we rounded when we calculated our scale factor of 0.002 cm/km. Where does that leave us? Well, in a really good position to explore or revisit rounding of numbers and to discuss when an "order of magnitude" answer is sufficient.

   To continue to create a model for this activity, use the actual ball radius in the calculations.

4. Determine the scaled distance between the center of Earth and the center of the Moon.

   $d_{E\text{-}M} = 384{,}430$ km
   Scaled distance $d_{SE\text{-}M} = (384{,}430 \text{ km}) * (0.002 \text{ cm/km}) = 769$ cm

5. The string will extend between the surface of the two balls, so the scaled distance needs to be adjusted.

   String Length SL = $d_{SE\text{-}M} - (r_{ball} + r_{SMoon}) = 769 \text{ cm} - (11.8 \text{ cm} + 3.5 \text{ cm}) = 754$ cm

6. Measure a piece of string the length determined in Step 5. Wait! Don't cut your string yet. Mark the string at the designated length. Measure off an additional 2 cm and cut the string there.

7. Use your model's scale to determine where on the string to mark the average orbital altitude of the

International Space Station. Mark this position on the string (from the previous mark back towards the length of the string).

d_{ISS} = 400 km * 0.002 cm/km = 0.8 cm

8. Attach the string to your ball with tape so that the first mark you made is at the surface of the ball. The International Space Station altitude mark should then be very close to the surface. Wrap the remaining string around the ball and you are ready to test your class's appreciation of how far away from Earth the Moon and the International Space Station orbit. The string should end up going approximately 9.5 to 10 times around the ball.

9. Note that at the scale used in our example, the scaled Moon would be comparable in size to a tennis ball or baseball.