Earth And Moon

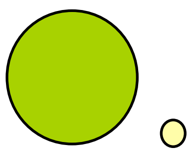
How large is the moon compared to the earth? What is the distance between the earth and moon? The answers might surprise you.

Materials Needed

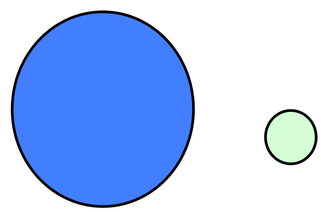
- an assortment of spherical objects (e.g. golf balls, tennis balls, basketballs, baseballs, racket balls, small marbles, larger marbles, etc.)
- rulers, tape measures, and meter sticks
- thin string
- modeling clay or double stick tape

Preparation:

- To start, you'll need to assemble a box of assorted balls. These can be purchased cheaply at large toy stores, warehouse type stores, and even some large chain convenience stores. *It is very important to purchase some combinations where one sphere is 4x the diameter of another sphere.* For example, the following sets of objects have this 4:1 ratio:



Tennis Ball & Small Marble



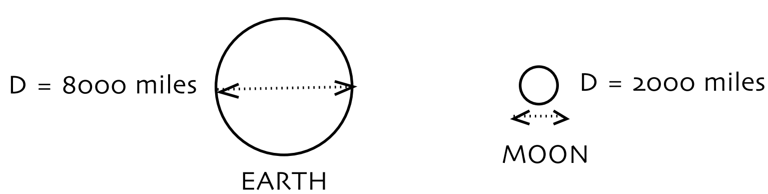
Plastic Toy Ball & Large Marble

What To Do:

Size of the Earth and Moon

- Have students work in pairs. Tell the students that they are going to be making a scale model of the earth and moon using the balls you are providing. Each pair selects the two spheres that they *believe* are closest to being the right relative sizes. *Reassure the students that they are making educated guesses*. Once the students have made their selections, ask each pair to take a moment to describe why they made the choices they made.

- Now tell students what the "correct" answer is. The diameter of the earth is about 8000 miles (12,800 km). The diameter of the moon is about 2000 miles (3,200 km). Did the students make the right choice? They will need to make measurements to determine how close they are. If they did not get the right pair of spheres, they can return to the box of balls you provided and pick another set of objects.



Linda Shore
Exploratorium Teacher Institute, 2004

Have each pair of students to use the measuring devices available to them to determine which sets of balls have diameters with a 4:1 ratio. There are many ways to go about this, and students should be encouraged use whatever technique (or multiple techniques) they wish to use to find the right balls to represent the earth and moon. Here are ways that the students might try…

1. Measuring Circumference:
   Let's consider the equation that describes the circumference of a sphere:

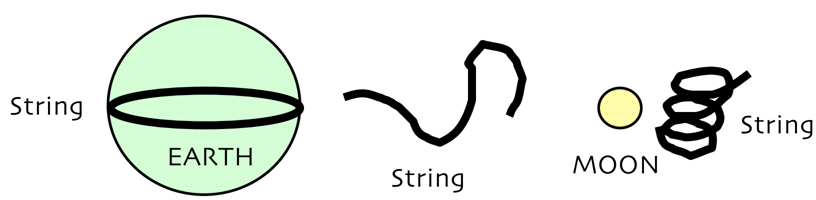
$$\text{Circumference (C)} = 2 \times \pi \times \text{radius} = \pi \times \text{diameter (D)}$$
$$C = \pi D$$

$$\frac{C_{\text{earth}}}{C_{\text{moon}}} = \frac{\pi D_{\text{earth}}}{\pi D_{\text{moon}}}$$

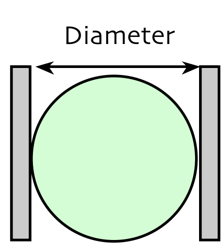
$$\frac{C_{\text{earth}}}{C_{\text{moon}}} = \frac{4 \times D_{\text{moon}}}{D_{\text{moon}}}$$

$$\boxed{C_{\text{earth}} = 4 \times C_{\text{moon}}}$$

   So, if the earth's diameter is 4 times larger than the moon's diameter, then the earth's circumference will also be 4 times larger than the moon's. Students can use the string to measure the circumference of the earth by wrapping it around the girth of the ball representing our planet. If this same length of string wraps around the ball representing the moon four times, then the two spheres are the correct size.

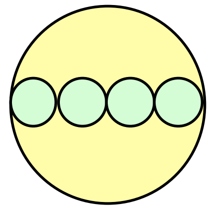


2. Measuring Diameter:
   Measuring the diameter of a sphere is not as easy as it seems. Be careful – many students will think that the diameter is measured directly along the circumference of the sphere and not through the sphere's center. To measure the diameter of the balls, students should use the "caliper" method and pinch each of the spheres between two parallel surfaces. The distance between the parallel surfaces will give students the diameter of the spheres. Books or pieces of stiff cardboard work well for the "calipers."

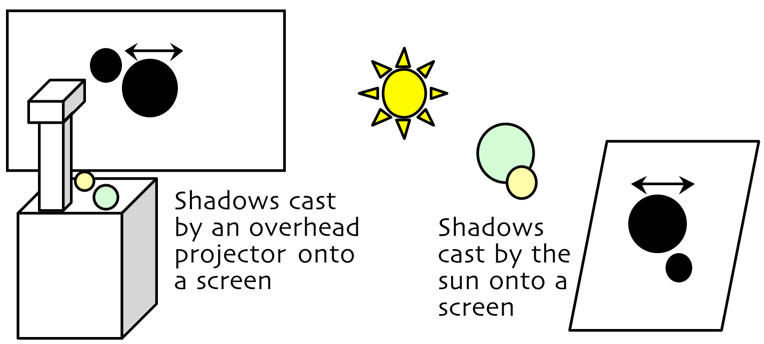


3. Lining Up Moons:

If the earth has a diameter that is 4 times larger than the moon's then 4 moons laid "end to end" will equal the diameter of the earth. Students may want to check the accuracy of their scale model by lining up 4identical moon models "end to end" and comparing the total length of this lunar line up to the diameter of their earth model.

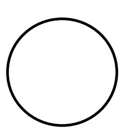


4. **Using Shadows:**
   Here's a clever way to do the "line up" method described above. Sometimes students have trouble judging whether the 4 moon models laid "end to end" equals the diameter of the sphere representing the earth. That's because the objects are three dimensional it is hard for many people to concentrate on just two dimensions at a time. Closing one eye to confound your perception of depth sometimes helps, and students should be strongly encouraged to try this. But another way to eliminate one of the dimensions is to examine shadows cast by the moon and earth models. You can cast shadows of the spheres by taking the models outside and using the sun as a light source. You can also place objects representing the earth and moon on an overhead projector and examine the shadows that will be cast on a screen. By measuring the diameter of the shadows, you can also determine whether you have the correct scale models.



Distance between the Earth and Moon

- Now that the students have found objects that represent the earth and moon at the proper scaled size, it's time for the students to *guess* at how far apart the two spheres should be to represent the distance between the earth and the moon. *Again, remind the students that they are making an educated guess.* Have the students place the two spheres on the floor (or on a flat table top) and use a small piece of clay (or double-stick) tape to keep the balls from rolling away.



Example of a student guess at the distance between the earth and moon models.

- Now tell the students what the correct answer is. The distance between the earth and moon is 240,000 miles (385,000 km). Since the earth's diameter is 8000 miles and

  240,000 miles/8000 miles = 30

  that means that 30 earth models laid "end to end" will give you the scaled distance between the earth and the moon models. Have students determine the diameter of their earth model and use meter sticks or tape measures to figure out how far away the moon model should be placed from the earth model.

  (Students can measure the diameter of the earth model using one of the techniques described in the first section. Then they can multiply the diameter by 30 to get the distance between the earth and the moon models.)

- Have students examine the distance between the earth and moon models. Are they surprised at how far apart the two objects are?

What's Going On?

Most people are very surprised when they see the scaled size and distance between the earth and the moon. Studies of the astronomy misconceptions held by students (and even adults!) reveal that most people believe that the moon is much larger and closer to the earth than it actually is. In fact, in a survey of thousands of US high school and college level students who had successfully completed an astronomy course, about 65% believed that the earth and moon were six earth diameters apart or less (the study was conducted by the Harvard Smithsonian Center for Astrophysics in 1989).

Why is this misconception so prevalent in students who have successfully completed astronomy courses where the "right" answer was covered in the curriculum? The answer lies in the diagrams found in most high school and college level texts. Most astronomy books fail to show the correct size and scale of the earth and moon. In fact, the majority of these books show the earth and moon as being less than 6 earth diameters apart – exactly what most students believe!

The power that text illustrations have in propagating misconceptions can not be underestimated. That is why it is important for students to articulate their beliefs about the size and scale of the moon and have experiences like this one that directly challenge their beliefs.

Size of the Earth and Moon

Diameter ~ 8000 miles

Diameter ~ 2000 miles

Distance between the Earth and Moon

Distance ~ 240,000 miles

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