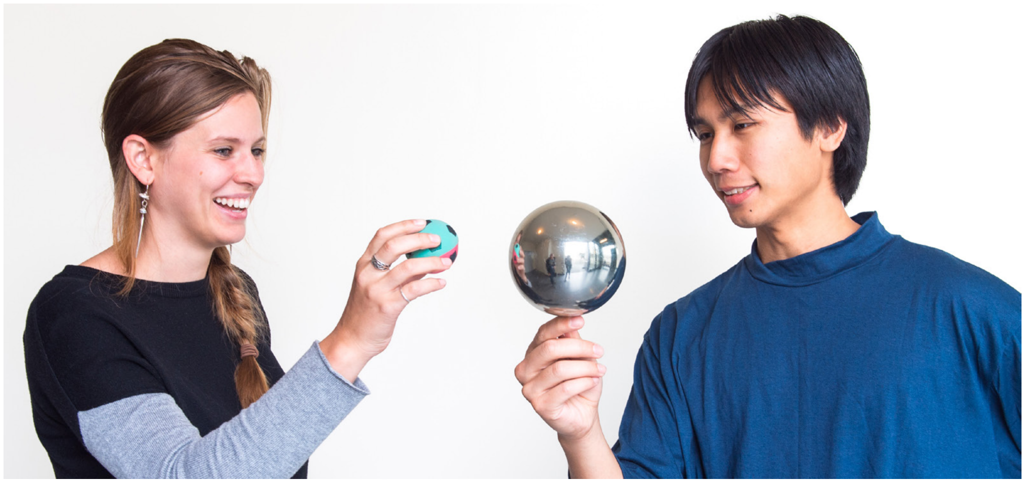
4th NGSS STEM Conference
MAKING SCIENCE COUNT
Integrating Math into an NGSS Classroom
January 20, 2017 | Pier 15, San Francisco, CA



Earth and Moon

Create a scale model of the earth-moon system using spheres of different sizes.

This Snack uses common objects to explore the relative sizes of the earth and moon and the distances between them. While exploring, participants will also learn to use their hands as measuring tools to see if their models are accurate.

Tools and Materials

- One pair of spheres whose diameters have an approximate 4:1 ratio for each pair of people. Possible pairs include:
  - Regular-sized marble (5/8-inch [1.5-cm] diameter) and tennis ball (2.5-inch [6.4-cm] diameter)
  - Rubber bouncy ball (1.0-inch [2.5-cm] diameter) and softball (3.8-inch [9.7-cm] diameter)
  - Billiard ball (2.25-inch [5.7-cm] diameter) and soccer ball (8.8-inch [22.4-cm] diameter)
  - Other spherical objects to try: ball bearings, different sizes of marbles and sports balls, and so on
- Box or bin to contain the spheres
- Measuring tapes and/or meter sticks

Assembly

None needed

To Do and Notice

To begin, place all the spheres in the box and ask each participant to choose one. Make sure each person has one of a pair so all can participate.

Investigation I: Determining the relative sizes of the earth and the moon

Once the spheres have all been chosen, tell participants that each sphere can be either the earth or the moon. Ask each person to find a partner whose sphere could represent the earth to their moon or the moon to their earth. Remind people to be flexible in their thinking, as one person's "earth" could be another's person's perfect "moon" (especially if many different kinds of spheres are involved)—or vice versa.

Once partners have paired up and settled on acceptable models, have them compare their choices. Have people who chose the same spheres made the same or different decisions about their partners? Usually, people will know that the moon needs to be smaller than the earth, but may not have much more information than that. Encourage participants to share their thoughts and ideas, and tell them they can switch spheres or partners if they decide they've put together incorrect pairs.

When everyone has settled into an earth-moon pair, reveal to the group that the diameter of the earth is four times the diameter of the moon. Have each pair check their decisions by making sure their moon fits four times across the diameter of their earth. Ask pairs to reconsider their choices once again. Do they need to change one of their spheres or their partner? Make measuring tapes available for those who want to check their choices, and help facilitate so all partners find correctly proportioned spheres for the next part of the activity.

Investigation II: Determining the relative distance between the earth and the moon

Once all participants have found a correct earth-moon partner, ask each pair to think about how far their moon should be from their earth. Remind people that different pairs of spheres will create different-sized models. Ask people to consider what they may already know about how far the moon is from the earth, and encourage them to share their thoughts and ideas. Again, make sure meter sticks and/or measuring tapes are available for them to use, though the use of non-standard measurements is also encouraged.

Once pairs have settled on an acceptable distance for their models, ask them to stand that far apart holding their spheres at their shoulders (for easy sight lines). As before, ask participants to compare their decisions with other pairs and make changes if they decide want to reconsider their choices.

Finally, reveal that the earth and moon, on average, are about 30 earth diameters apart. Ask people to check their models. Using a meter stick or measuring tape or another method, each pair needs to separate their earth from their moon by 30 times the diameter of the model's earth sphere. Once that's done, each pair will have made a scale model of the earth-moon system.

What's Going On?

One challenge of presenting scale models in astronomy is the difficulty of modeling both the size and distance of two (or more) celestial bodies simultaneously. It's helpful to think about the correct ratios and sizes by simplifying the numbers. In this activity, it's easy to remember that four moon diameters will fit across one earth diameter, and thirty earth diameters will fit between the moon and earth.

Investigation I: Determining the relative sizes of the earth and the moon

Most people's ideas of the relationship between the earth and moon come from photos and illustrations that may exaggerate the size of the moon in relation to the earth. As a result, participants probably started by creating pairs in which the moon was smaller than the earth (which is correct), but larger than the correct ratio dictates.

The moon's diameter is actually 2,159 miles (3,476 km); the earth's diameter is 7,926 miles (12,756 km). By simplifying these measurements (in miles), it's easy to remember that the earth's diameter is about 8,000 miles, and the moon's diameter is about 2,000 miles. The ratio of the two is about 4:1, meaning that the earth's diameter is four times greater than the moon's diameter, and that four moon diameters will fit across one earth diameter.

Investigation II: Determining the relative distance between the earth and the moon

When asked to place their spheres the correct distance apart, most people will settle on a spot that puts their model earths and moons much closer together than they should be.

The average distance between the earth and the moon is 238,857 miles (384,404 km). If we round up this number (in miles) for simplicity, the result is 240,000 miles. The ratio of this distance to the diameter of the earth (8,000 miles) is about 30:1, meaning that the moon and the earth are about 30 earth diameters apart.

Going Further

Now that each pair in the group has created a scale model of the earth-moon system, let's see how we can use these models to learn more.

Try this: Have each pair remain at their model distances. Ask each "moon" partner to hold his/her "moon" sphere next to one eye. "Earth" partners are now viewing a correct scale model of the full moon.

Ask each "Earth" partner to extend his/her arm, elbow straight, to see which part of the extended hand is the right size to barely cover the "moon." Ask pairs to trade spheres with their partners and repeat this, so each person can try the same experiment. What do they discover? Can they fine-tune their models using this technique?

The full moon subtends, or sweeps out, about 1/2 degree of arc in the sky. The correctly placed moon in each of these scale models does the same. When looking down your straightened arm, half the tip of your little finger sweeps out about 1/2 degree of arc as well. Most people are surprised by how "small" the full moon appears in the model. People should be encouraged to check their results the next time they see the moon in the sky!

By coincidence, the sun also subtends 1/2 degree of arc in the sky. (Please don't look at the sun to try to measure this!) Although the sun is much, much larger than the moon, it is also much, much farther away. As seen from the earth, each of these—the sun and the moon—sweeps out 1/2 degree of arc in our sky. Therefore, during a total solar eclipse, the moon blocks out the sun perfectly and completely.

Check out the Handy Measuring Tool Snack to learn more about how to use your hands to make indirect measurements: exploratorium.edu/explore/video/handy-measuring-tool-science-snacks

Teaching Tips

Be sure to emphasize that only linear measurements, such as the earth's diameter, are four times larger than that of the moon. Students should not assume that the earth is four times "bigger" than the moon, unless they can explain what they mean by "bigger." The earth's surface area and volume are not four times that of the surface area and volume of the moon!

If you are a teacher leading a class in this activity, be sure to establish some appropriate use guidelines for your students—otherwise the spheres will be all over the room!