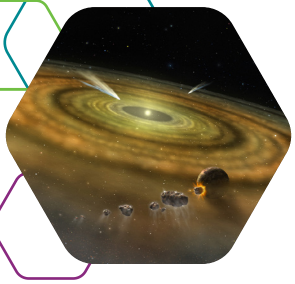

FACILITATOR GUIDE
Moonquakes

Learning objectives

- The Moon is a very different place from our home planet, but there are similarities.
- Both earthquakes and moonquakes result from a sudden release of energy and cause the ground to move and shake.
- NASA missions study moonquakes and other processes on the Moon's surface to learn more about the Moon itself and to prepare for the return of humans.

Materials

- Earth and Moon Venn diagram
- Sorting cards
- Scarf hanger
- 3–5 spring toys
- 3–5 small carabiners
- Moon (& optional Earth) ball
- Apollo Landing Sites map

The Explore Science toolkit comes complete with all necessary materials for this activity. Materials are also readily available online or at local retail stores to create or restock activity kits. Graphic files can be downloaded from *www.nisenet.org.*

Safety

Spring toys can become entangled in loose and dangling jewelry, hair or clothing. Ensure that jewelry is secured and hair is kept away from the spring toy.

Advance preparation

Before you begin:

- Set out the Earth/Moon mat and sorting cards, and place the Moon and Earth balls nearby.
- Clip 3–5 spring toys on the scarf hanger using the small carabiners. Set aside.
- Set aside one spring toy to be used to demonstrate wave compression.

Notes to the presenter

The spring toys are an enticing (and distracting) material for visitors! To keep people's attention during the first part of the activity, place the Earth/Moon sorting cards closer to the participant's side of the table, and try keeping the spring toys closer to you. You can even keep them hidden until you are ready to use them. The Moon ball or Apollo Landing Sites map can help invite some Moon questions as participants approach your table.

CARD-SORTING ACTIVITY

The introductory sorting card part of the activity is meant to be a quick exercise that allows the facilitator and participants to talk about various natural processes that occur or don't occur on Earth and the Moon, and potential ways we could detect and measure these phenomena. The answer (Moon, Earth, or Both) can be found on the flip side of each card. Talking about these cards can help highlight that the Moon has practically no atmosphere, so "weather" on the Moon is very different from what we experience on Earth. Invite participants to consider how conditions on the Moon (such as lack of oxygen and liquid water, low gravity, extreme temperatures, and moonquakes) might impact future lunar exploration.

You can also use the Moon ball in combination with the sorting activity as an attraction on the activity table. And after the spring toy demon, you can use it to get participants thinking about where and when past Moon missions placed scientific instruments to help record moonquakes.

Try discussing the quake card last as a natural transition into the next part of the activity.

MAKE A "QUAKE"

Start by using a loose spring toy to model how waves move through the coils. Ask a participant to stand 4–5 feet away from you. Hold one end and invite a participant to hold the other. Try moving your end up and down or in and out from your position. What happens—how does the waves travel to the other end? What else can you try?

Working together with several participants, make a model of a moonquake. You'll need to have at least two participants, and this works with up to five other people. Each participant will need to hold the end of one spring toy, with the other end attached to the hanger with a carabiner. Try to avoid bunching up the carabiners on the hanger loops. The hanger will allow you to manipulate multiple spring toy at once.

Stagger two or more participants at various distances, radiating out in a circle with you at the center holding the hanger. Instruct one participant to stay nearby (about 3–4 feet away), one to go far away (8–10 feet away), and scatter other participants between these distances. Be cautious not to place anyone too far to avoid overly stretching the spring toys.

Move your (the facilitator's) end of the spring toy while the participants hold the opposite end in one hand. Invite participants to raise their other hand as soon as they see or feel the wave traveling through the spring toys. In your model, the participants are acting as the “seismographs” on the Moon—the instruments that detect when a moonquake occurs. Participants might need to practice raising their hands as soon as they see or feel the motion to become more accurate detectors of simulated qukes. They can even close their eyes if they prefer to focus on feeling for the incoming wave. Encourage them to have their hand ready as soon as they detect the motion. Try it out together to fully get the hang of it!

If you don’t have a group to create the full model, you’ll need to do a bit more explanation about how quake movement radiates away in all directions from the origin. Try asking the participant to start close to you then move further away to observe the differences in wave arrival times.

CONVERSATIONAL PROMPTS

When discussing quakes, it may be useful to have the participant start by describing an earthquake. Try asking them, “Have you ever been in an earthquake? Have you ever seen one in a movie or on television? What happens to people? Buildings? Roads?” Discuss why it’s useful to understand quakes here on Earth. Why is this knowledge important to society? How can earthquake data be used when planning a city or constructing tall buildings?

Before doing the spring toy demonstration with a whole group, ask the participants if they think quakes move in one direction from the source (like along just one single spring toy)? Try demonstrating with just one of the spring toys. Then, using the hanger and spring toy model, explain that the hanger represents the origin of the quake; the spring toys represent the waves caused by the quake; and the participants (staggered out at various distances) represent quake measurement tools, called seismographs. Ask the participants what they observed. In what direction did the waves travel from the center? Ask, “Have you ever observed waves behaving this way before?” One of your participants may bring up ripples in water. Some participants may connect waves travelling in all directions to a time when they heard a loud explosion or fireworks.

Ask the participants to *predict* who will feel the “quake” first. Why do they think it will happen in that order? What do they notice? Explore the concept that seismic data collection becomes more accurate when there is more than one seismograph. For an older audience, ask your participants why scientists require three seismographs to pinpoint the origin of a quake. Discuss as a group why this might be so, or how having fewer than three seismographs might impact our ability to find the starting location of a quake.

After the demonstration has been conducted a few times, have the participants come together for a final discussion about moonquakes. Use this time to talk about how the seismographs left by NASA’s Apollo astronauts on the Moon were responsible for much of what scientists know about moonquakes. The Moon ball or map graphic can be used to find the six Apollo landing sites with participants. You can also share plans for NASA’s upcoming Artemis mission—returning astronauts to the Moon to search for water ice and explore potential sites for a long-term outpost. Before building future human settlements, scientists must consider quakes and other conditions on the Moon’s surface. Try asking, “How will quakes on the moon impact continued human exploration of the Moon?”, “What could scientists and engineers do now to protect future astronauts and instruments?”, and “What will future astronauts have to do to be prepared for a possible moonquake?”

Difficult concepts

Many people believe there's no gravity in space, but gravity is everywhere, even between the Moon and Earth. The Moon has less mass compared with Earth, so the gravity on its surface is also less—about ⅙ of the gravity we experience on Earth.

The Moon doesn't experience wind, rain, snow, storms, or other forms of weather like we do on Earth due to its lack of liquid water and extremely thin atmosphere—but that doesn't mean surface conditions on the Moon never change. There are extreme temperature changes on the Moon comparing daytime and nighttime. In fact, some of the coldest known spots in our solar system are the permanently shadowed craters located near the Moon's South Pole.

Models are used to help us think about phenomena that are not easy to observe or understand. This activity uses a model of a quake where seismic waves are represented in the movement of a spring toy. This model adequately represents the movement of a wave, but doesn't represent the medium or material that the wave moves through as well (there is no spring toy in real life, the wave actually travels through the rock.) While our model is a great first step toward understanding seismic wave patterns, there are still many details it does not address. Models are not perfect and can't accurately represent all aspects of a phenomenon.

Background

Earthquakes typically result from movement in the Earth's crust as large pieces of the Earth's surface (tectonic plates) drift away or crash into each other. This movement is caused by convection in the Earth's hot and active mantle. The Moon's internal structure is more rocky and cooler than the Earth's—there are no known active volcanoes on the Moon.

Because of these differences, scientists were surprised when moonquakes were first detected. After studying seismic data collected by NASA's Apollo missions, scientists concluded that quakes on the Moon are caused by (1) *tidal forces* as the Moon travels closer to or farther from the Earth (2) *temperature changes* as different parts of the Moon experience day and night; (3) *shrinkage* as the deeper layers of the Moon continue to cool, and (4) *space objects* (asteroids, comets, or meteoroids) striking the surface and causing vibrations. Quakes on the Moon appear to be less forceful than those on Earth, but may last longer.

Additionally, Moon landings have caused quakes. The quakes caused by later Apollo missions were helpful in confirming that the first seismic instruments were working.

GOING FURTHER WITH THE DEMONSTRATION

On Earth and on the Moon, vibrations in the ground during a quake move in several different ways. Two of these waves—called seismic waves—are referred to as *P-waves* (primary compression waves) and S-waves (secondary shear waves). The P-waves and S-waves **information sheet** for this activity has more information about these kinds of waves—including plots of each waveform and a seismograph recording sample. The facilitator working with one participant can use a single spring toy to model both types of waves.

- To demonstrate P-waves, hold one end of a spring toy and hand the other end to a participant. Ask them to step back at least 3–4 feet. While holding your end of the toy, bunch up some of the coils at your end and release them to give a gentle push out towards the participant. Invite the participant to notice how each coil bumps into the next coil, resulting in a quickly moving "migrating bunch" that travels down the length of the spring. (This demonstration might work better with the spring toy lying flat on a smooth floor.)
- To create S-waves, start off using the same arrangement as above—the facilitator and participant each holding their end of the spring toy at least 3–4 feet away. This time, quickly move your end back and then forth once so it moves in an "S" or snake-like pattern. Once again, try this on a smooth floor for better results. Invite participants to notice how this side-to-side wave moves more slowly than a P-wave.
- Try doing a side-by-side race of the two with an open question to participants about which they think is slower or faster.

Staff training resources

Refer to the *Tips for Leading Hands-on Activities* sheet in your activity materials.

- Content Training Video: *https://vimeo.com/441410284*
- Activity Training Video: *https://vimeo.com/441410208*
- Edu-Cathalon Facilitation Training Video: *https://vimeo.com/304241578*

The NISE Network has a curated list of programs, media, and professional development resources that directly relate to the toolkit. These resources can be viewed and downloaded from: *www.nisenet.org/earthspacekitextensions*

Credits and rights

This activity was adapted from Exploring Seismic Waves, developed by Incorporated Research Institutions for Seismology. Retrieved from: *https://www.iris.edu/hq/inclass/lesson/31*

Earth and Moon structure illustration and sorting card icon artwork, Emily Maletz Graphic Design for the NISE Network.

Earth, Moon, Apollo 11 seismograph, Buzz Aldrin setting up the Apollo 11 seismograph experiment, Moon crater, and Moon surface images courtesy, NASA.

Image of Slipher Ridge ridge courtesy Mark Robinson, LROC/ASU.

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