Space Science

How Big is the Moon?

https://www.youtube.com/watch?v=ogtoGZR4E4Q&list=PLa3BRSex0pXzgivsqrJuvjyXCFKylfmUu&index=10

Passport Question: The Moon is much smaller than Earth and the Sun, but it can still block the Sun during a total **solar / lunar** eclipse because of perspective. (Circle one)

Passport Answer: The Moon is much smaller than Earth and the Sun, but it can still block the Sun during a total **solar** eclipse because of perspective.

Background Information:
The Moon is only **1/50th** the size of Earth in terms of volume! That means if Earth were hollow you could fit 49 Moons inside it. The Sun's volume is roughly **1.3 million (1,304,000) times** greater than Earth's and **6.4 million** (**63,926,940) times** greater than the Moon's.

Even though the Sun is much larger than the Moon, they appear the same size in the sky, and the Moon can completely block the Sun during a **total solar eclipse**. It's all a matter of perspective! Because the Moon is much closer to Earth than it is to the Sun, when the Moon passes in between Earth and the Sun, it can block the Sun's light by casting its shadow on Earth.

Training Video: https://vimeo.com/191171673

Materials:

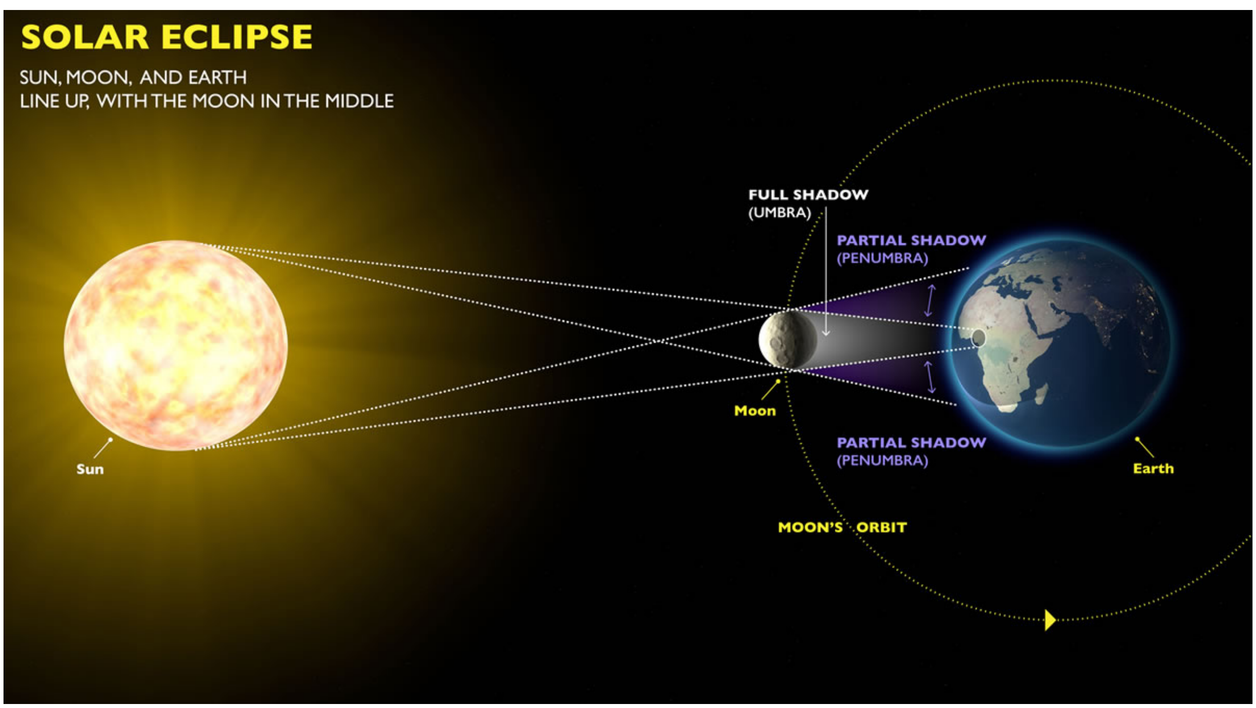
- Play-Doh
- Butter Knives
- Templates with 50 rectangles labeled 1-49 (Earth) and 1 (Moon)
- Images of solar eclipse
- Image of Sun to place on the wall

Procedure	
1	Ask students: *Which is bigger, Earth or the Moon?* Ask them to guess how much bigger. This is their hypothesis. Ask: *Which is bigger, Earth or the Sun?*
2	Take a piece of Play-Doh and roll it into a long cylindrical shape. Set the Play-Doh against the template and cut it at the grey "Moon" rectangle so that you have two pieces, one 49 units long, and the other 1 unit long.
3	Roll each of the pieces into spheres. The large piece is Earth and the small piece is the Moon. Ask students: *Are you surprised?* Tell them ***the Moon is 50 times smaller than Earth.*** Ask students: *How about the Sun? How big would it be in comparison?* Tell them: ***On this scale, the Sun would need 64 million pieces of Play-Doh!***
4	Ask: *Has anyone seen a solar eclipse before?* Prompt students about the 2017 eclipse, if they remember it. Ask *does anyone know what causes a solar eclipse?* Show a picture of the solar eclipse. *A **solar eclipse** is when the Moon crosses between Earth and the Sun, blocking the Sun's light and casting a shadow on Earth. How can our tiny Moon block the giant Sun during an eclipse?*
5	Have students think about how someone seems smaller when they are far away and bigger when they are closer. Another fun example is "squishing" someone's head between your thumb and pointer finger when they stand far away from you.

	Clearly, their head is much larger than your fingers but you are able to “squish” their head because they are so far away.
6	Tell students to block the Sun image on the wall using either their Earth or Moon models (<u>NOTE</u>: This part of the activity is not to scale. The Sun would actually be much larger than the picture, but the scientific concept still holds.) Tell them they are Earth and their Play-Doh moon is the Moon. Allow them to experiment and figure out how to eclipse the Sun with the Moon.
7	Answer any questions, and prompt them to think about the discussion points below:

Discussion:

- The Sun and Moon appear nearly the same size in the sky because the Sun's diameter is about 400 times larger than that of the moon and the Sun is also about 400 times farther from Earth.
- The average distance between Earth and the Moon is 250,000 miles. For comparison, the next closest object is Venus with an average distance of 25,000,000 million miles. The distance from Earth to the Sun is 92,170,000 million miles. In astronomical terms, the Moon is right on top of us!
- Total solar eclipses are very rare—they are only possible when the Moon is crossing Earth’s orbital plane, which only happens twice a year, AND is in the new Moon phase. They often occur in the middle of the ocean, so it is even more rare when they are visible from cities and towns on Earth. You may remember the total solar eclipse when the Moon’s shadow crossed the United States in 2017!
- A **total solar eclipse** is what we most often refer to as an “eclipse.” A lunar eclipse is when Earth is directly between the Sun and the Moon, causing the moon to appear reddish in tint, which is why it is sometimes called a blood moon!
- Partial solar eclipses occur when the Moon is not directly in the Sun’s path, but still casts a shadow visible from Earth.



[Pocket Solar System](https://www.youtube.com/watch?v=Ox3bPsqR4cc&list=PLa3BRSex0pXzgivsqrJuvjyXCFKylfmUu&index=11)

https://www.youtube.com/watch?v=Ox3bPsqR4cc&list=PLa3BRSex0pXzgivsqrJuvjyXCFKylfmUu&index=11

Passport Question: Name the planets in our solar system in order of their distance from the Sun: M__, V__, E__, M__, J__, S__, U__, N__

Passport Answer: Name the planets in our solar system in order of their distance from the Sun: Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune.

Background Information:
What does our solar system look like? Building scale models of the solar system is a challenge due to the vast distances and huge size differences involved. This is a simple, small model to give students an overview of the distances between the orbits of the planets and other objects in our solar system. NOTE: While the distances are to scale, the planet images we use are not.

Materials:

- 1 completed Pocket Solar System for reference
- 1 meter per person of receipt paper
- Meter stick
- Planet sheet
- Scissors
- Glue sticks
- Recycling bin
- Folding guides: 2 English, 1 Spanish, 1 Pink Facilitator Guide
- Decorations: solar system poster, images of planets to scale, mnemonic device posters

Training video: https://vimeo.com/191168509
More planet information: https://solarsystem.nasa.gov/
Folding guide: https://www.nisenet.org/catalog/exploring-solar-system-pocket-solar-system

Procedure	
1	Ask the students: *Do you know the order of the planets? Which planet is furthest from the sun? Which planet is closest to Earth?*
2	Give each student a meter length of paper tape, a sheet of planets, scissors, and a glue stick. Tell the students *We're all going to do each step of this together.* Instruct students to cut around the planets as small as possible while still retaining the planet name.) Students can cut the planets out at the beginning or as they do the activity. Use the pre-made pocket solar system and the pink folding guide as a reference.
3	Have them place the Sun at one end and the Kuiper Asteroid Belt at the opposite end. (Note: Pluto was reclassified from a planet to a dwarf planet in 2006. It is a part of the Kuiper Belt.)
	Fold the tape in half and crease it. Unfold and lay it flat. Ask students which planet they think will be right in the middle and why. They might be surprised to know that the planet that goes at the **½ mark is Uranus** (Note: Pronounce this planet "your-in-us").
	Refold the paper in half and fold it in half again (you should now have fourths). At the halfway point between Uranus and the Kuiper belt, place **Neptune (3/4 mark)**.

	At the halfway point between Uranus and the Sun, place **Saturn (1/4 mark)**.
4	Stop and inspect your work. *We've only placed the 3 most distant planets. That means that we've still got 5 planets and the asteroid belt to fit into the quarter between the Sun and Saturn!*
5	Fold the Sun up to Saturn and crease it. Unfold and lay flat again. Place **Jupiter** at the halfway mark between the Sun and Saturn **(1/8 mark)**. If you take a look, you've got the four gas giants on there. For the remaining bodies in the Solar System, you'll only need inner 1/16th of your tape length!
6	Fold the Sun out to meet Jupiter to mark the **1/16 spot**. A planet does not go here, but the **Asteroid Belt** does. Explain that many things besides planets orbit the Sun, including asteroids and comets.
7	At this point, things start getting a little crowded, folding is tough, and it's hard to get precise distances. (Note: it's best to stagger the planets to fit the remaining ones. Don't place them all in a straight line.) Fold the Sun to the Asteroid Belt mark and crease it. Place **Mars** on this **1/32** fold (between the Sun and Asteroid Belt).
8	*How many more planets do we need to place?* Three. Fold the Sun up to meet the line for Mars. Leave it folded and fold that section into an even smaller half. Unfold the tape and you should have three creases. *Do you know the order of the remaining planets? Make some guesses.* Place **Earth** on the **3/128** crease nearest Mars, **Venus** on the middle **(1/64)** crease, and **Mercury** on the **1/128** crease closest to the Sun.
9	Smooth out your model and admire your work. *Are there any surprises when you look at the distances between the planets this way?* Many people are unaware of how "empty" the outer solar system is (there is a reason they call it space!) and how "crowded" the inner solar system is (relatively speaking). *How was this different from what you imagined?*
10	Tell students they can keep this pocket solar system to remember how far apart the planets are. Then direct them to the **mnemonic device or "memory sentence"** posters. Explain that they can make up a sentence to help them remember the order of the planets. A common one is "My very educated mother just served us nachos." Our sentence will include a "K" word at the end for the Kuiper Belt. Tell them they can write their own "memory sentence" on the back of their pocket solar system using the words on the wall, or they can make up their own.

Discussion

- The Sun is the only star in our solar system (there are no other stars sprinkled throughout.)
- The solar system is inside the Milky Way Galaxy (not in the center), which is part of the universe (but also not "in the center"). Students may confuse these vocabulary words and use them interchangeably.
- The large amount of space between planets still contains things like dust, plasma, and light, so it isn't truly "empty."
- Our **Solar System** is made up of planets, moons, asteroids, comets and other objects that orbit the Sun.
- Many of the planets in our solar system are relatively close to the sun, while the Gas Giants (Jupiter, Saturn, Uranus, and Neptune) are much further.
- There are eight planets in the Solar System. Pluto, the former ninth planet, was renamed a "dwarf planet" in 2006 due to its small size (it's smaller than our Moon!).
- <u>Notes from NASA on Pluto:</u> "Pluto is a dwarf planet that lies in the Kuiper Belt, an area full of icy bodies and other dwarf planets out past Neptune. Pluto is very small, only about half the width of the United States and its biggest moon Charon is about half the size of Pluto. Almost all the planets

travel around the Sun in nearly perfect circles. But not Pluto. It takes an oval-shaped path with the Sun nowhere near its center. What's more, its path is quite tilted compared to the planets."

- Although we usually think of the Solar System as planets, there are many other objects orbiting the Sun. The Asteroid Belt is a loose collection of rocky asteroids orbiting between Mars and Jupiter. Astronomers believe they are leftover materials from the formation of the Solar System that never came together to form a planet or moon.

Cooking Up Comets

Passport Question: Name two ingredients that make up comets.
Passport Answer: Ice, frozen gases, rocks, dust, organic material

Background Information:
Comets are small objects that orbit the Sun and are made of frozen water, rocks, dust, and frozen gases such as ammonia, methane and carbon dioxide. They are created from some of the materials left over after the formation of planets. Much of these materials were lumped together to form planets. But, the remaining amounts circulated in the outer edges of our solar system where temperatures were cold enough to produce ice. In this activity you will "cook" a comet to show what one might look like up close.

Ingredients:
- Water (1 cup)
- Dry Ice
- Sand
- Ammonia
- Molasses or dark corn syrup

Materials:
- Cooler
- Hammer
- Heavy Duty Yard Trash Bag
- Construction Gloves
- Metal Bowls (2)
- Large Metal Spoon
- Measuring cup
- Lab Coat and Goggles

More information on Comets vs. Asteroids: https://spaceplace.nasa.gov/asteroid-or-meteor/en/
https://solarsystem.nasa.gov/asteroids-comets-and-meteors/meteors-and-meteorites/in-depth/

Procedure	
1	Put on safety goggles and gloves! This activity involves dry ice and **students must not touch the comet with their bare hands.** Say: *Everyone needs to be conscious about safety! I am wearing my Personal Protective Equipment (PPE) that includes gloves and goggles. Whoever handles the dry ice must wear PPE.*
2	Have all ingredients and utensils arranged in front of you. Cut open a garbage bag and use it to line your mixing bowl. **A comet is a body of ice, rock, organic material, and dust that can be several miles in diameter and orbits the sun.** *As our Solar System cooled, it gathered dust to make small rocks which then gathered together to make even bigger rocks, which ended up forming the planets and moons! Comets are the leftover bits of frozen water and rock that were not incorporated into larger planets and moons. Think of them as the bits of dough left in the bowl when you make cookies!* It may help to distinguish the differences among comets, meteors, asteroids, etc. using the definitions and pictures provided.
3	Place **1 cup of water** in mixing bowl. *The water in comets is frozen because it is so cold in space.*
4	Add **one spoonful of sand**, stirring well. *You can't buy interplanetary dust at the store. So, we have to use sand in its place! Luckily, sand has the same minerals and compounds found in comets.*

5	Add a **dash of corn syrup**. *This represents organic material. Organic material means anything made up of <u>carbon, hydrogen, nitrogen and oxygen</u>! Every living thing on Earth is made of organic material.*
6	Add a **dash of ammonia**. Stir while talking. *Ammonia is another organic compound found in comets. When you help clean the windows, it's with some of the same chemicals found in comets!* Continue to stir until well mixed.
7	**Be sure to wear gloves while handling dry ice.** Take a **large chunk of dry ice** out of the cooler and place in a separate garbage bag to smash. Use the hammer and smash the dry ice to a "snow cone consistency." Take approximately 1 cup of the dry ice and add it directly to the mixing bowl.
8	Stir vigorously. *Dry ice is frozen carbon dioxide, the same gas that makes bubbles in soda. When a comet is far from the Sun, its carbon dioxide is frozen into dry ice just like this!* Continue stirring until mixture is almost frozen. *We are stirring up this comet because that is just like the rotation of the comet as it orbits through space around the sun.* Lift the comet out of the bowl using the plastic liner and shape it as you would a snowball. Unwrap the comet as soon as it is frozen enough to hold its shape.
9	*Observe the comet!* As it begins to melt, the students may notice small jets of gas coming from it. These are locations where the gaseous carbon dioxide is escaping through small holes in the still frozen water. This is also detected on real comets, where the jets can sometimes expel enough gas to propel the comet in another direction and change its orbit.

Discussion:

- Comets have several distinct parts:
    - a nucleus made of ice, frozen gases, dust, small rocks, and organic material, usually 1-10 km in diameter;
    - a coma which is a dense cloud of water and gases that have evaporated from the nucleus;
    - a long **dust tail** made of tiny particles evaporated from the nucleus, which reflects Sunlight and is the most visible part of the comet; and
    - a very long **iong tail** composed of electrically charged gas molecules pushed away from the nucleus by solar wind.
    - hydrogen envelope—trails along between the dust tail and the ion tail;
- Comets are invisible most of the time except when they are near the Sun because they need Sunlight to reflect off of their particles to be seen. They don't give off their own light.
- Most comets have elongated elliptical orbits that take them close to the Sun for a part of their orbit, and then out into the further reaches of the Solar System for the remainder.
- Some scientists believe that comets were the source of Earth's water and possibly organic compounds during our planet's early formation approximately 4.5 billion years ago.
- <u>Comet</u>: A body of ice, rock and dust that can be several miles in diameter and orbits the sun. Debris from comets is the source of many meteoroids.
- <u>Meteoroid</u>: A small rocky or metal object, usually between the size of a grain of sand or a boulder, that orbits the sun. It originates from a comet or asteroid.
- <u>Meteor</u>: A meteoroid that enters the earth's atmosphere and vaporizes. Also called a "shooting star."
- <u>Meteorite</u>: A meteor that hits Earth without burning up in the atmosphere.

- Meteor shower: A collection of meteors visible when Earth passes through a trail of debris left by a comet.
- Asteroid: An object larger than a meteoroid that orbits the sun and is made of rock or metal.

<u>Meteorite Impact!</u>

Passport Question: Name two variables that affects the size and shape of a crater
Passport Answer: Size of meteorite, speed of meteorite, angle of impact

Background Information:
A **crater** is the remains of a collision between an asteroid, comet, or meteorite and a planet or Moon. Craters can be found on many planets including Mercury, Venus, Earth, and Mars. The size, speed, and angle of the falling object determine the size, shape, and complexity of the resulting crater. Small, slow objects have a low energy impact and cause small, simple craters. Large, fast objects release a lot of energy and form large, complex craters. Very large impacts can even cause secondary cratering, as ejected material falls back to the ground, forming new, smaller craters. In this activity students will experiment to see how craters of different shapes and sizes are formed.

<u>NOTE</u>: How to set-up the Moon model. This should already be done prior to volunteer's arrival. Directions: In a pie pan, create the surface of the Moon by filling the pan first with flour (about half of the large sifter) and then sift cocoa powder (about half of the small sifter) over the top to create contrast.

Materials:
- 9" Pie Pans (6) or larger trays
- Flour (~5 lbs. per day)
- Cocoa Powder (2-3 containers)
- Fine Sifter
- Hand Strainer
- Golf Balls (6)
- Marbles of different sizes (6)
- Ping-Pong Balls (6)
- Small, Non-Spherical Rocks or Pebbles (6)
- Rulers (6)
- Bucket (3 gal)
- Drop Cloth
- Meteorite Impact! Data sheets
- Images of Moon's surface, craters on Earth, and secondary craters

Procedure	
1	*Have you noticed the craters in the moon? Craters are caused my **meteorites** that hit the surface of the moon and create a dent. Craters can be big, small, oval-shaped, circular, deep, or flat. Show students an image of the surface of the moon. Ask if anyone wants to make a **hypothesis** about what causes the different shapes and sizes of the craters.*
2	Explain that to test a hypothesis we need to change the **independent variables** *one at a time.* Brainstorm some variables we could change (the height the meteorite is dropped, the angle of impact, and the size, shape, and type of meteorite). Have the students make hypotheses before dropping any "meteorites." Be sure that they change **only one independent variable** at a time. Introduce the activity sheets here. You can even do a quick demo by filling out your own sheet and dropping a ball. Warn students to be responsible with the "meteorites" or the "Moon surface."
3	Begin the experiment! Use a ruler to measure the drop height and the diameter of the crater. Be sure to record the results! Let the student do this for a few minutes. You can monitor their progress by making sure they are filling out their sheets and not making a mess.

4	*Were the students' hypotheses correct? Why or why not? What have they learned about how craters are formed?*
5	Compare the surface you created to the pictures of the surface of the Moon. *Using what you now know about craters, what can you tell from looking at these images?*

Discussion:

- Meteorites hit at a wide range of speeds, but the average is about 12 miles per second.
- Erosion from wind and water on Earth has worn away existing craters, making them less visible.
- The surface of the Moon is scarred with millions of impact craters. Unlike Earth, there is no atmosphere on the Moon to help protect it from potential impactors. Most objects from space burn up in Earth's atmosphere, making meteors.
- Since there is no erosion and little geologic activity to wear away the craters on the Moon, they remain unchanged—until another object hits!
- Most of the craters on the Moon are circular, but some are more oblong-shaped.

Jumping on Jupiter

Passport Question: Our weight changes on other planets because each planet has a different ____________ which affects its ____________.

Passport Answer: Our weight changes on other planets because each planet has a different mass which affects its gravity.

Background Information:
How far you can jump and your weight depend on **gravity**. Gravity depends on a planet's **mass**—or how much STUFF it's made of. Smaller planets usually have less mass and therefore less gravity so you weigh less and can jump farther than you can on Earth. Larger planets usually have more mass and more gravity so you weigh more and can't jump as far or high as you can on Earth. Students will demonstrate this with some simple calculations and a demo with spheres of different masses.

NOTE: It is recommended to take the containers of beans from the Jumping on Jupiter activity to help illustrate the impact of mass on gravity.

Materials:
- Scale
- Tape Measure
- Blue Painter's Tape: tape out 3 meters on the floor and label
- "Jumping on Jupiter" worksheets
- Pencils
- Calculators (6)
- Solar System poster
- Poster-sized graph paper (one for Earth and one for Jupiter, axes labelled ahead of time)
- Stickers in four colors (red=3rd, yellow=4th, green=5th, black=adult)

Procedure	
1	Show students the solar system poster. *On which planet do you think you can jump the farthest? Why?*
2	Have students line up on the starting line one at a time and challenge them to see how far they can jump on Earth! Make sure that they note where they land. Give students the correct color sticker for their grade level and help them graph their jump on the "EARTH" graph.
3	Tell them, *you can jump farther on different planets because there is less gravity holding you down*. Look at the "Jumping on Jupiter" worksheet and complete the chart to determine how far you can jump on each planet.
4	Check their work before they can take the same colored sticker and place it on the "JUPITER" graph. Tell students they can check back throughout the day to see if anyone beats their jumping record.
5	If time permits: *Based on what you just learned, on what planet do you think you would weigh the most? Why?* See how much you weigh on Earth and complete the opposite side of the worksheet.
6	*On what planet could you jump the farthest? Were your predictions correct?*

7	*If your body stays the same, why does your weight change on each planet?* Hint: *What do you notice about the planets where you weigh more?*
8	Bonus question: *What do you think you would weigh in space?*

Discussion:

- *What is the difference between weight and mass?* We often use the words "mass" and "weight" as if they were the same, but to an astronomer or a physicist they are completely different things. The mass of a body is a measure of how much matter it contains. **Matter** is anything that takes up space—it can be a solid, liquid or gas. You, me, the lake, the air, Earth, they are all made of matter and have mass.
- Weight is related to mass. Simply put, weight = mass x gravity. You can measure your weight by standing on a scale—the force of Earth's gravity pulling on you is your weight!
- *So what is the difference between mass and weight?* Your mass is always the same no matter where you are, but your weight changes depending on the gravity of planet you're on.
- Space by definition is empty—it has no matter. Without matter it can't have mass or gravity. In space, your weight would be zero!

Moon Dance

Passport Question: An object spinning around on its axis is _________. An object circling around another object is __________.

Passport Answer: An object spinning around on its axis is rotating. An object circling around another object is orbiting.

Background Information:
A **rotation** is an object spinning around on what is called an **axis** (an imaginary line down the middle). It takes a day for Earth to do one full **rotation** on its **axis**.

An **orbit** is when an object circles another object, such as Earth going around the Sun. It takes a year for Earth to **orbit** the Sun. Just as Earth orbits the Sun, the Moon orbits Earth.

The Moon doesn't make any of its own light—it only reflects light from the Sun. In this activity we will see how this reflected light causes the phases of the Moon.

Materials:
- Flashlights (1 for each pair of students)
- Styrofoam spheres
- Toothpicks

Procedure Part 1: Space Carousel	
	Before beginning the main activities (Moon Dance and Time of the Seasons), there are three important concepts to make sure everyone knows: ***rotation***, ***axis***, *and* ***orbit***.
1	Have the students stand in a circle around you in the room. Tell them to turn around in place. *What is a scientific word for what you are doing?* **Rotation.** *Does Earth rotate?* Yes. *How long does its rotation take?* One day.
2	If you could draw a line down the center of your rotation, *where would it be?* They should indicate down the center of their bodies. This time, hold your right arm straight over your head and then rotate. *What does your arm represent?* Your **axis**, the imaginary line right down the middle of a rotation.
3	Now, ask the students to walk around the circle. *What is a scientific word for this?* It's an **orbit**. An orbit is when an object circles around another object regularly. *Does Earth orbit?* Yes. *How long does its orbit take?* One year.
4	Earth rotates and orbits at the same time. Have the students complete another orbit while rotating! *So, what's the difference between an orbit and a rotation?*

Procedure Part 2: Moon Dance	
1	*Ask students why the Moon looks different every night. What is a new Moon?* Once, or sometimes twice, a month the Moon disappears from our view. This is called a **new Moon**, and it happens when the illuminated side of the Moon faces away from us. *What is a full Moon?* At a **full Moon**, Earth, Moon, and Sun are in approximate alignment, just as the new Moon, but the Moon is on the opposite side of Earth, so the entire Sunlit part of the Moon is facing us. The shadowed portion is entirely hidden from view.

2	Group the students in pairs and give each pair a flashlight and a sphere. The person with the flashlight is the Sun, the person with the sphere is Earth, and the sphere is the Moon.
3	Give directions to the students: Each pair stands facing each other a few feet apart. Earth holds the Moon in front of them at arm's length and a little above their head. The Sun holds the flashlight a little above their head and shines it straight at the Moon.
4	*Ask Earths to describe what the Moon looks like to their partner.*
5	Tell Earths to rotate very slowly to their left, holding the Moon in the same position. The Suns should stand still and continue shining the light straight at the Moon. *Ask Earths to stop every two small steps and describe what the Moon looks like. What do they see?*
6	Once Earths have rotated all the way around, they switch roles with their partners. The new Earths do the same activity, describing the Moon as they slowly rotate.
7	Have the students discuss these questions with their partners and then ask a few people to share their answers: *Where is the Moon when we see a new Moon? Where is it when we see a full Moon?* *Where does the Moon's light come from?* *Why does the Moon's appearance in the night sky change?* *How would you eclipse your Moon?*

Discussion:

- As the Moon orbits our planet the amount of Sunlight it reflects changes. When the Moon is on the far side of Earth the Sun's light hits the side facing us, causing a full Moon. When the Moon is between Earth and the Sun, the side facing us is dark, causing a new Moon.
- When the Moon is less than half full is it a crescent; half full is a quarter (because it is ¼ through its cycle); and more than half full is called gibbous. As the shape grows from new to full it is waxing, and as it shrinks back to the new Moon it is waning. In the Northern Hemisphere the Moon is waxing when the lit area is increases from the right to the left. Which means it's waning when the lit area is decreases from the right to the left. Therefore you can tell if the Moon is waxing or waning based on whether the right side of the Moon is dark or light. Waxing = Right side lit, Waning = Left side lit. In the Southern Hemisphere the effect is just the opposite!)
- *Why do we always see the same side of the Moon?* The Moon orbits Earth because it is pulled by the planet's gravity. Earth's gravity "drags" the Moon so that it rotates at the same speed as it orbits (both of which take about 27 days). So we always see the same side! The "dark" side of the Moon is the side that we never see from Earth, although it's not actually dark—it's lit up during the new Moon.

Time of the Seasons

Passport Question: What causes seasons on Earth to change?
Passport Answer: The tilt of Earth's axis.

Background Information:
We all know that it is cold in the winter and hot in the summer, but have you ever thought about why that is? People hold a lot of misconceptions about what causes the seasons and this activity will teach the scientific reason for the seasons.

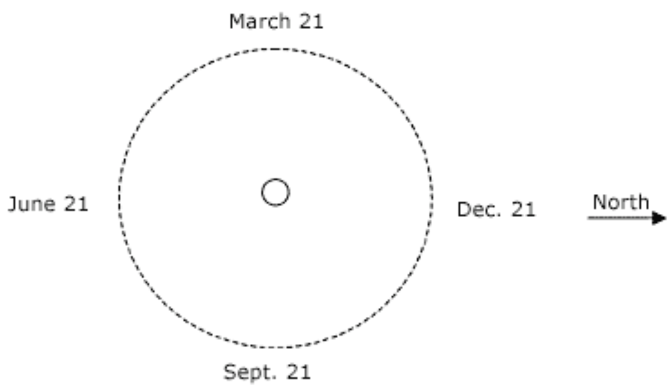
The seasons are caused by the tilt of Earth's axis. Earth holds its tilt fixed in space as it moves around the Sun. Our planet is tilted at 23.5 degrees and is "pointing" towards the North Star, Polaris.

Materials:

- Lamp
- 4 large Styrofoam spheres
- 4 rubber bands
- 4 stands
- 4 thumbtacks
- Protractor
- Station markers labeled December 21, March 21, June 21, and September 21
- North Star image

Procedure	
	Students have just learned about rotation, axis, and orbit and how the Sun's light creates the phases of the Moon. Now they will see how the Sun cause the seasons.
1	Ask the students what they know about the seasons. *Why do we have seasons?* Let students answer without correcting them.
2	Divide the students into four groups and give them an Earth model. On this model the sphere represents Earth, the dowel is the axis, the rubber band is the equator, and the thumbtack is our location in Tahoe. (*You can also ask students what they think each component represents before explaining*.) *Where is Earth's* ***axis****? What do you notice about it?*
3	Place the model near the Sun (the lamp) and with the axis pointing toward the image of the North Star (behind December). Have each group slowly turn the dowel so that Earth spins to the left for one rotation. *Ask them to make observations about the dot with their group.*
4	They should see that the dot is in light (day) for about half of the rotation and is in shadow (night) for about half of the rotation. This **rotation** is called a day!
5	Now place one group at each of the dates: December 21, March 21, June 21, and September 21 (see setup below). Have each group model a day at each position, making sure that Earth's axis is tilted towards the North Star. Students should make observations with their group.
6	*For what fraction of the day is the dot in the light? More than half? Less than half? About half? How is the light from the Sun striking the dot? Is it direct or at an angle?*
7	After a couple of minutes, move the groups to the next date and have them discuss

	the same questions. Do this until they are back at the date they started at. It is very important that Earth's axis is tilted towards the North Star each time!
8	*What have you modeled?* A year is the time it takes for Earth to **orbit** the Sun.
9	*Which group is in summer (June 21)? How do you know (besides the date)? How does the Sunlight hit the dot and for how long? Which group is in winter (December 21)? How does summer and winter Sunlight compare to spring and fall Sunlight?*
10	Based on your observations, *what causes the seasons on Earth?* To further show the point, take one Earth out of the stand and have it orbit with the axis straight up. *Would we have still have season if Earth's axis was like this?*
11	Bonus questions: *Are the seasons in the Southern Hemisphere the same? Why or why not? What happens to the North Pole in winter? Summer? Why?*



Setup for Steps 5--9

Discussion:

- Many people think the seasons are caused by variations in our distance from the Sun. While Earth's orbit is slightly elliptical, it's very close to circular, and the variation in distance between Earth and Sun is not enough to account for our seasons.
- In the summer, the Northern Hemisphere tilts toward the Sun. It's warmer because there are more hours of daylight, providing us with more heat energy, and the midday Sun shines more directly head on, increasing the amount of solar energy Earth receives.
- In the winter, when the Northern Hemisphere tilts away from the Sun, the Sun's rays strike Earth at a lower angle, and the energy from the Sunlight is spread out over a larger area, which reduces its effectiveness at heating the ground. Combined with shorter daylight hours, the temperatures are cooler in winter.
- Because of the tilt, the seasons in the Northern and Southern Hemispheres are opposite. Summer in California is winter in Brazil!
- In winter, Earth is tilted so that Sunlight never reaches the North Pole. It is dark there for 24 hours each day. In summer, the opposite happens, and the North Pole has 24 hours of Sunlight each day.

[The Fabric of Space-Time](https://www.youtube.com/watch?v=KY-cpwJPel8&list=PLa3BRSex0pXzgivsqrJuvjyXCFKylfmUu&index=9)

https://www.youtube.com/watch?v=KY-cpwJPel8&list=PLa3BRSex0pXzgivsqrJuvjyXCFKylfmUu&index=9

Passport Question: What holds planets in orbit around the Sun?
Passport Answer: Gravity

Background Information:
How do the planets stay in orbit around the Sun? The key is **gravity**. Every object with **mass** (made of matter) has some gravity, and the greater the mass, the greater the gravity. The Sun, has a lot of mass and, therefore, a lot of gravity to pull on the planets with!

This gravity model allows students to experiment with planetary motion. This activity is more of a guided exploration than a lesson. The goal is that students see that the marbles **orbit** around the object with the most **mass**, representing the planets orbiting the Sun. For example, the mass of the sun is about 333,000 times the mass of the Earth.

NOTE: The model is NOT accurate. The marbles eventually fall into the center and the planets don't! The difference is **friction**—the spandex slows down the marbles, but, in space there is no material to slow the planets down. So, they orbit continuously! While the model isn't accurate, it's a great lesson! *Emphasize that friction is the difference.*

Materials:
- 7 36" 1.25" PVC pipes
- 14 PVC T-connectors
- 14 34" .75" PVC Electrical Conduit
- 28 .75" to 1.25" Connector (PVC-1 D2466 IPS 1 x 1/2)
- ~ 72" x 72" piece of Lycra/spandex (Comes in 48" width rolls)
- 20 clamps
- 2 1lb weights
- Marbles
- Other small spheres (ping pong balls, Styrofoam balls, etc.)

Procedure	
1	Lay out the ground rules for this activity: Students must be gentle with the marbles and the model, and they cannot go underneath the model for safety reasons.
2	Begin with no weight on the model. Roll a few marbles around. *What happens?*
3	Place one weight in the center of the model. Ask for predictions of what the marbles will do when rolled onto the sheet. *What is the difference?* The marbles should move much more quickly down towards the weight.
4	Demonstrate how to roll the marbles: they should be rolled gently but with speed toward the edge of the model (it may take some practice to get it down!).
5	Allow students to explore what they can do with the model. If they seem stuck, prompt them with these ideas: What if we use spheres of different sizes? What if we roll marbles in opposite directions? What if we add a second weight to the model? What if we roll a small sphere and a big sphere together?

Discussion:

- *If everything with mass has gravity, then wouldn't the planets pull on the Sun too?* They do! The Sun has a slight "wobble" due to the pull of the eight planets around it. However, since the Sun has so much more mass than the planets, the effect is very small.
- *Why do the planets orbit the Sun instead of the Sun orbiting a planet?* Because of mass and gravity, the object with less mass always orbits the object with more mass.
- *Why do the planets stay in orbit?* Newton's first law of motion says that an object in motion will stay in motion unless something acts on it. The planets stay in orbit because there is nothing in space to push or pull them, unlike the marbles in our model that are pushed against by friction.
- *If the Sun's gravity is pulling on the planets, why don't they fall into the Sun?* In addition to falling toward the Sun, the planets are moving sideways—VERY fast! The force of the Sun's gravity and the speed of the planets are balanced. Amazingly, the planets are falling towards the Sun but because they are moving so fast that they "overshoot" the Sun and travel in a circular path.

Exercise like an Astronaut/Exercising in Space

Passport Question: Do objects weigh more on Earth or on the Moon?

Passport Answer: Objects weigh more on Earth.

Background Information:
Astronauts must exercise twice as hard in space to maintain their strength. Since there is very little gravity on the International Space Station, it requires less strength to operate daily tasks. Because of this difference, when astronauts return to Earth they are much weaker than when they left. So to maintain their strength, astronauts must exercise more frequently and harder than when they were on Earth!

Materials:

- Non-breakable containers labelled “3,000 Beans on Earth” and “3,000 Beans on the Moon” (6)
- Tape (to seal containers)
- Dried beans
- Paper (to stuff inside cans so they don’t rattle)
- String

Procedure	
Set-up	Place three cups of beans into Earth container and ½ cup of beans into the Moon can. There are approximately 3,000 beans in 3 cups. Tightly seal each can with tape. Place cans on an outline so students know where to return them. If there is no facilitator, ask another to keep an eye out on the activity. Make back-up cans in case some go missing.
1	(NO FACILITATOR REQUIRED.) Students lift Earth can with one hand and the Moon can with the other. They compare how different 3,000 beans feel on Earth vs. the Moon. These cans represent the same amount of beans—they just feel different because there is less gravity on the Moon! The amount of mass a planet has effects its gravity. Earth has more mass than the Moon and therefore more gravity. So, a can of 3,000 beans feels heavier on Earth than it does on the Moon.

Discussion:

- *Do you think astronauts must work out more frequently to be prepared for space?*
- *Would you have trouble working out in zero gravity?*
- *What are some creative ways you can think of that would make working out in little gravity a bit easier?*
- *Reduced gravity will lead to a loss of calcium in the bones and weaker muscles. During the space mission, resistive exercises and good nutrition can help offset some of these changes. Once they return to Earth, astronauts continue to exercise to strengthen their weakened bones and muscles. Scientists keep a careful watch on astronauts before, during, and after flights in space.*

Working in Space

Passport Question: Circle the reasons that astronauts must wear protective spacesuits and gloves: It is cold in space, there is no oxygen in space, the spacesuit provides protection and a means for survival for the astronaut. **Passport Answer:** All of the above.

Background Information:
When in space, astronauts need to be able to leave the space station to complete repairs, make observations, or take samples. But life in outer space can be very dangerous! Astronauts must wear a spacesuit and thick gloves at all times. Without this special equipment their bodies could begin to swell twice their normal size! But the thick safety gloves also make completing simple tasks very difficult. In this activity, students will see just how difficult!

EVA Gloves - Astronauts must be able to work with and pick up objects while wearing spacesuit gloves. EVA gloves are made to protect astronauts from the space environment. They are also made so spacewalkers can move their fingers as easily as possible. The fingers are the part of the body that gets coldest in space. These gloves have heaters in the fingertips. A piece called a bearing connects the glove to the sleeve. The bearing allows the wrist to turn. (From NASA: https://www.nasa.gov/audience/foreducators/spacesuits/home/clickable_suit_nf.html)

Materials:

- Trifold display board
- NASA gloves
- Legos
- Tub (to place Legos in)
- String
- Tape

Procedure	
Set-up	Place some Legos in a small tub on table. Tape string around the bottom of gloves (multiple rounds around the base of the glove work best to secure them). Tie the other end of the string to the table leg or tape securely to table. Make sure there is just enough slack in the string for students to move glove—but not too much as the activity should still be slightly challenging.
1	NO FACILITATOR REQUIRED. Students read the board and directions. Students put on gloves and attempt to build a small structure out the Legos. This activity simulates how difficult it can be to move small pieces while wearing thick safety gloves.

Discussion:

- *In space the largest danger is a lack of oxygen or an ebullism (different from embolism). Ebullisms are caused by the formation of bubbles in body fluids due to a reduction in ambient pressure. This is similar to when a diver experiences "the bends." The pressure in the vacuum of space is so low that the boiling point of your bodily fluids drastically decreases. Your blood won't boil but you can swell up to twice your natural size.*
- *Also, there is no oxygen in space. So astronauts must always have a large supply of oxygen when venturing out of the space station.*
- *Would you still want to travel in space?*

- *Was it difficult to build a structure using the gloves? Can you imagine how challenging this might be for astronauts?*