Caltech Geological and Planetary Sciences Outreach Outdoors

***Note:** sections of the lesson plan template marked with * are optional, but may be useful for your planning.

The Phases and Eclipses of the Moon!	
Grade level	6-8
Standards	MS-ESS1-1. Develop and use a model of the Earth-sun-moon system to describe the cyclic patterns of lunar phases, eclipses of the sun and moon, and seasons.
Goals	- Students will discover the position of the moon relative to the earth and sun during a new moon, quarter moon, and full moon through self-demonstration - Students will recreate the conditions for a solar eclipse and lunar eclipse
Time	45 minutes
# students	1-40
Materials	- Completely dark room (room with no windows or dark shades, maybe a library or gym if not the classroom) - Lamp with bare light bulb or lantern - Styrofoam balls on sticks
Location	Any room where the windows can be blocked and the lights can be turned off, so the only light source is the central lamp. If the classroom has weak blinds and there is stray light, the activity will not work very well
Logistics	Handing out the balls on sticks and arranging the students in a circular formation around the central lamp
Caltech student needed?	No, but the Caltech student can provide the supplies, help with leading the lesson, and answer questions
Accessibility	Students must be able to see the illumination on the styrofoam ball to illustrate the phases of the moon. A tactile moon could be created for visually impaired students (see the moon

	phases and eclipses section in module 1 here http://depts.washington.edu/astron/outreach/astronomy-for-the-sight-impaired/).

Lesson activities

Engage: (20 min)

- Introductions: Guests say their name/what kind of science they do/favorite planet, students can also say their favorite planet
- Begin by getting the class excited about the moon - tell them we are sending astronauts back to the moon and highlight the local astronauts, and tell them why the moon is important (controls the tides, keeps earth's rotation period 24 hours, is beautiful to look at, etc.)
- Now ask the students a series of questions about their experiences with the moon to get them prepared for the activity. A PowerPoint companion to this lesson walks through some images with question prompts, including:
  - How did the moon get there? (giant impact with a mars-sized object)
  - What is the moon made of? Is it rocky like earth, with a metal core, or something else? (It has an inner metal core and outer rocky mantle like the earth, but no crust doing plate tectonics or atmosphere like the earth).
  - Have you ever seen features on the moon? What did they look like? (craters, lava fields, etc.)
  - Have you ever seen the moon during the day time? How is that possible? (Since the moon doesn't shine on its own, we can only see the light that the moon reflects from the Sun. Sometimes during the early morning or late evening when the daylight is not too bright, you can see the moon against the blue sky more faintly than it appears at night).
  - What are the different shapes of the moon that you've seen? When was it brightest? Why might one full moon have been brighter than other full moons? (The moon's distance to Earth changes as it orbits, sometimes it is closer to Earth when it's full which causes "Super-moons").
  - Have you ever seen the moon looking more yellow or red than white? Where was it in the sky? Why might that be? (When the moon is low in the sky near the horizon we are looking through more atmosphere to see it, so the moon looks more orange closer to the horizon for the same reason why sunsets are red.)
  - Have you ever seen a lunar eclipse? What color was the moon? Why do you think it was that color? (You can tell the students that the moon is red during a lunar eclipse if nobody has seen one before. A lunar eclipse is red for the same reason that the sky is blue. The Sun shines all colors of the rainbow onto Earth, but the Earth's atmosphere scatters the blue light more than the red light. The red light that is scattered less goes on into space and hits the moon during the eclipse!)

- Why do the lunar phases occur? (The moon is orbiting the Earth, and reflecting sunlight from different angles relative to our viewpoint). Allow the students to propose their own hypotheses without directly answering for now, since they will be able to test them in the next activity
- Remind the students that they've been making scientific observations about the moon during their lives, they just never realized it. The moon is important to us because it controls the tides, and it stabilizes the rotation of the Earth. Does anyone have a guess for how long it takes to reach the moon? Will the moon always be there?

Explore: (30 min)

- Give each student a styrofoam ball that has been poked onto a stick
- Spread the students out into a circle that surrounds the central lamp, and give them a warning that we're about to turn off the light and pretend we're the Earth floating in space and orbiting the Sun
- Turn all the lights off in the room so the only light source is the lamp
- Ask the students to face directly away from the lamp and hold up the styrofoam ball an arm's length away and at the level of their head
- Tell the students that the lamp represents the Sun, their head represents Earth (and their nose is the location of Pasadena on Earth), and the ball is the moon.
- Ask the students what they see – is the side of the "moon" they are looking at illuminated? How much of the whole moon is illuminated? What phase of the moon does this represent (full moon)?
  - Note: if the students are holding the ball directly in front of their head, the shadow of their head may block the ball and cause it to not be illuminated. This represents a lunar eclipse, and you can either ask the students what scenario this might be or come back to it later and ask the students to hold the ball slightly above their head for now.
- Ask the students to turn 90 degrees (a quarter turn) to their left – how much of the moon is illuminated now? What moon phase does this represent? (quarter moon)
- Again, ask the students to turn 90 degrees to their left. They should be facing directly towards the lamp now – how much of their moon is illuminated? What phase of the moon does this represent? (New moon, it should be dark)
- Now allow the students to spin around on their own, noticing the changes in how the moon is illuminated as they turn – point out the crescent phase right after new moon when they continue turning to the left, and the gibbous phase between the quarter moon position and the full moon. You can also point out how the arc of the shadow line on the moon (the "terminator") goes from concave to convex after the moon is more than half full, and ask if anyone has heard of "waxing" and "waning" lunar phases and what they mean

- While the students are exploring their own views of the different moon phases, ask how long they think it takes for them to experience every possible phase, based on their experience seeing the moon at different phases in the night sky (one full rotation or orbit of the moon around the Earth is about a month - 28 days).
- Now ask the students to stand facing the lamp and place the ball directly between their eyes and the bulb (and remind them not to stare into the bare bulb). This is simulating a solar eclipse. Has anyone ever seen this before? Ask them why this doesn't happen every time the moon orbits around the sun (the moon's orbit is tilted relative to Earth's equator, and a solar eclipse can only happen during the daytime).
- Ask the students to simulate a lunar eclipse now – stand directly away from the lamp and block the moon with the shadow of the Earth – their own head.
- Finally, ask the students to change their imagination. Now, instead of the styrofoam ball on the stick representing the moon, let it represent the earth. Ask them to hold the Earth out in front of them while facing the lamp, but tilt it so that the stick points slightly towards the lamp. This represents the Earth's axial tilt. Ask them which season it is in their town when the stick (Earth's northern hemisphere) is pointed towards the Sun vs away. Explain that the Earth's axis is consistently pointed in the same direction, so as it orbits around the Sun, sometimes the northern part of the Earth is angled towards the Sun, and sometimes it's angled away.
- Mention that there's a dark side of the moon that they didn't see

Discuss

- Ask the students to check out the moon next time they see it in the sky! They can try and guess which phase it is before looking it up – it gets hard to tell once the moon is nearly half full. Encourage them to look up the moon's rise and set times, and have a look at the moon shortly after it rises, while it's low on the horizon and the most beautiful, or to look at the moon with binoculars or a telescope so that you can see the incredible detail on the craters.

Evaluate?

- Ask the students to all show a full moon phase (they should face away from the lamp), then a new moon (towards the lamp), then a half moon phase (either the lamp on their direct left or direct right).
- Ask the students what their favorite new fact that they learned about the moon is

Instructor support

- Some topics may arise naturally but prematurely in the lesson plan as the students explore their view of the moon with the lamp on (e.g. what happens when I cover up the sun with the moon? Why does the moon not cover the sun

every time it orbits around the earth?) – feel free to address these questions as they arise and let the students lead the learning.

Common misconceptions about the lesson

- Why don't we see the moon every night?
    - Because of the Earth's rotation – sometimes the only time the moon is visible from our location on Earth is during the daytime when the Sun is too bright to see the reflected light from the moon