Moon Mission

A Guide for Family ASTRO Leaders

PROJECT ASTRO

From Project ASTRO™

Astronomical Society of the Pacific

"Moon Mission" was developed by educators at the Astronomical Society of the Pacific with funding from the National Science Foundation. It is part of a series of "Family ASTRO" kits and activities being developed at the nonprofit Society.

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Moon Mission Web Site:
http://www.astrosociety.org/education/family/resources/moon.html

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Dear Family ASTRO Event Leader,

Welcome to the "Leaders' Guide" for Moon Mission, a kit of astronomy activities to introduce families to our nearest neighbor in space. Besides this guide to leading lunar family events, your "Leader Kit" also contains some materials that can be reused in future family events and a copy of the family take-home kit that can be given out at your family events.

A typical Family ASTRO event involves a mix of three kinds of activities:

Stations: These are brief stand-alone projects that can be explored by families, typically at the beginning of an event, without much instruction from event leaders. The concepts introduced at the stations will be reinforced in other activities. For Moon Mission events, we encourage you to have two activity stations at each family's table rather than around the room.

Facilitated: These are activities that you will actively lead during your event. They usually require more time, explanation, and direction than the stations. For Moon Mission, they also include the second part to the "Our Changing Moon" and "Crash Landing!" station activities. In the case of the former, there is a demonstration to be completed before the debriefing.

Take-home: These activities are meant for families to do on their own after your event; however, we set aside some time at the end of the suggested second session for you to briefly introduce the material. Families have many choices when considering how to fill their discretionary time and we want these activities to compete successfully with their other choices. So they are more fun and game-like, and for Moon Mission, we've created a fun, cooperative board game for the whole family.

On the next page, you'll find a materials list, including things we have provided in your Leader Kit (besides the master sheets in this Leaders' Guide), plus materials that you will need to find on your own. Following the materials list, sample agendas are included to help you organize two family event sessions. The activity write-ups that follow include instructions on what you need to do in advance to prepare. If handouts are required, the masters are all here in this Leaders' Guide.

Remember in planning your family event to leave a bit of time for questions, discussion, restroom breaks, and snacks. When you have done all the activities that time allows, it's good to do a wrap-up. Review the main points of what the group has learned, encourage everyone to do the take-home game, and preview the next family astronomy event you are going to hold.

We are eager to hear from our partners who try these activities so we can continue to improve them and add new ones. Contact us at: astro@astrosociety.org with your anecdotes and suggestions. Best of luck with your events, and we hope you have fun as you share your enthusiasm for exploring the Moon.

Clear Skies,
The Family ASTRO Team

Materials List

What's Included in the Leader Kit

- ***Moon Mission: A Guide for Family ASTRO Leaders*** (or "Leaders' Guide," which you are reading). It **includes all masters** that you will need to photocopy.
- **Moon Mission Game** Family Take-home Activity (Leader's Sample Copy)
- **"How to Start Right in Astronomy"** courtesy of Sky & Telescope Magazine. (See the Moon map on last page)

For "Our Changing Moon"

- Styrofoam balls
- Set of lunar transparencies

Materials You'll Need to Get

General Materials for Most Activities

- Colored markers
- Scissors, 1 per family
- Glue sticks, 1 per family
- Flip chart and markers (or equivalent)
- Scratch paper
- Pencils
- Masking tape and Scotch tape

For "Our Changing Moon"

- Working light bulb (e.g. table lamp with shade removed)
- Extension cord
- Room that can be fully darkened
- Overhead projector and screen (optional)

For "Sizing up the Moon"

- 5 plastic knives
- Cutting board or sheet of wax paper
- Piece of string 7.5 feet long
- 1 pound of playdough for each family

For "Moon Jump"

- Flip chart paper (27″ x 34″), at least 2 sheets per family
- Calculators (optional)
- Stool or stepladder (for taping paper to wall)
- Measuring sticks or tape (e.g. yardstick), one per family

Moon Mission Family Event

Sample Agendas

Each Family ASTRO Leader Kit is designed for two full family events. Because families may attend the first session with enthusiasm, but not a lot of knowledge, it is important to schedule a second follow up session. This gives families a chance to digest some of what they have learned in the first session, continue their learning at home, and then have the opportunity to come back with questions. Answering questions and encouraging new interest are key components of Family ASTRO's positive impact on family learning.

Session 1 • Time Needed: 90 Minutes

Time Needed	Activity	Notes
15 minutes	Toad in the Moon, Our Changing Moon, part 1	Welcome families individually as they arrive. Encourage them to complete the station activities at their table. If snacks are provided, point them out and allow families to snack while working. Both station activities should be done by all families.
10 minutes	Welcome and Debrief Toad Station	Call the group together and make sure everyone has signed in and has a name badge. Explain agenda and have each family share a Moon story from the Toad activity.
20 minutes	Our Changing Moon, part 2	Families get to check their own work from the Changing Moon station using two new pieces of information: demo with Styrofoam ball and map of the Full Moon.
20 minutes	Sizing up the Moon	Families construct a scale model of the Earth/Moon system using playdough.
15 minutes	Moon Jump	Families measure how high each member can jump on Earth and then calculate how high each could jump on the Moon.
10 minutes	Evaluation	Families appreciate this opportunity to give input and their comments may help you plan your next activity.

What's Next:

- Remind families about the date and time of the second session and that a fun new game will be played.

Moon mission Family Event

Sample Agendas Continued

Session 2 • Time Needed: 90 Minutes

Time Needed	Activity	Notes
15 minutes	Crash Landing	Welcome families individually as they arrive. Encourage them to get started on the activity at their table. If snacks are provided, point them out and allow families to snack while working.
15 minutes	Welcome and Debrief	Call the group together and make sure everyone has signed in and has a name badge. Explain agenda. The Crash Landing activity can lead to pretty extensive discussion if people come up with creative alternative uses for the items recovered. Be sure to leave time for discussion here.
10 minutes	Game Introduction	Take a few minutes to introduce the unique features of the Moon Mission game. Tie in to some of the environmental discoveries made during the Crash Landing discussion and to how Moon phases look from Earth and can serve as a timer for the game.
40 minutes	Game Play	Take a moment to interrupt game play to find out what questions have come up.
10 minutes	Evaluation	Families appreciate this opportunity and their comments may help you plan your next activity.

What's Next:

- Invite families to participate in another Family ASTRO event; give the topic with a teaser for what they will learn.
- Follow up with a star party: Invite volunteers with telescopes to set up for family observing with an opportunity to explore the lunar features.

12 Key Ideas for Working with Families

from Family ASTRO

Website: *www.astrosociety.org*

1. Be flexible, and always have an alternative activity or approach in mind. Be prepared with some thing for families to do who finish early.

2. Make it all fun, not just educational. Show them you're enjoying it too.

3. Be inclusive. Prepare for children and adults of many ages and skill levels. Make sure that every one has a role that feels important to him or her, and has opportunities for success throughout the event.

4. When introducing activities, try to give people a "hook": a problem or puzzle to solve, or some skill to learn. (For example: "If you crashed on the Moon, what would be the most important tools to help you survive?")

5. When doing an activity, get quickly to what there is TO DO; save any detailed background information for after you have them hooked.

6. Materials must be ready to go. While students in a class may be used to waiting while you set up, families will be less patient.

7. Throughout the event, allow for as much active participation as you can.

8. Set up the room so that family members sit together. Or, try seating two families at one table so that the groups can share their results.

9. It's best to explain by doing; demonstrate what you want families to do as you explain it. If you want them to build something, build one first and then give them materials to build their own.

10. Try to have two people helping with each family event, so that the person in charge of a particular activity can remain focused on the group and not just on the demands of a few individuals.

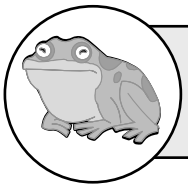
11. After each activity, be sure to provide closure. Review what just happened and allow families to share their experience with the activity.

12. Provide food whenever you can (even snacks make a big difference).

Toad in the Moon

by Suzanne Chippindale

An Activity for the Whole Family from Project ASTRO



- **Type of Activity:** Station and Facilitated
- **Set up Time:** 5 minutes
- **Time to Do:** 7-8 minutes for station, 10 minutes for facilitated

What's This About?

There are as many stories about the patterns on the face of the Moon as there are cultures who have looked at it. In this activity, families will be introduced to the variety of characters seen there by different cultures and are invited to create their own.

Materials Included

- Family Instructions master (page 11)
- Full Moon Story Sheets masters (pages 13-25)
- Black and white image of the Full Moon Family Worksheet master (page 27)

Materials You'll Need to Get

- Pencils
- Colored markers
- Masking tape

Setting up the Activity

- Make photocopies of Story Sheets, Family Instructions, and Full Moon Worksheet (pages 11-27)
- Place one Full Moon Story Sheet on each family table (use a different story on each table)
- Place two to four blank Full Moon Worksheets on each family table (and have extras available)
- Make sure each family has pencils and markers available

Doing the Activity

This starts as a station activity, so it requires little introduction. Families are asked to draw one or more characters from the light and dark spots on the face of the Full Moon directly on the photocopy of the Full Moon Worksheet. The characters can be modern or mythical, and personal to their family or not. During the facilitated debrief, ask each family to share their creation. Tape the drawings up on the wall to share with the group.

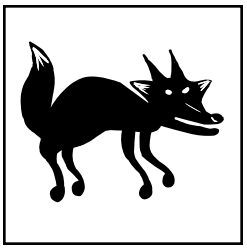
This activity will serve as an ice breaker to get families using their imaginations. All other activities will be treating the Moon as a member of the Solar System and as something to be explored. In this activity, they explore cultural connections to the Moon and astronomy.

Toad in the Moon

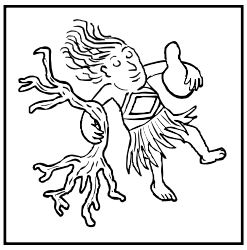
What do you see in the face of the Moon?

BY SUZANNE CHIPPINDALE

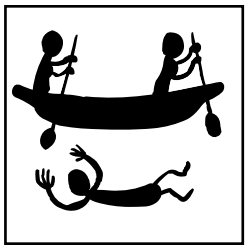
An Activity for the Whole Family from Project ASTRO



Fox - Peru



Woman - New Zealand

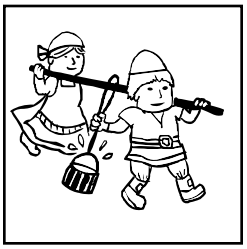


Man - Australia

Toad - China

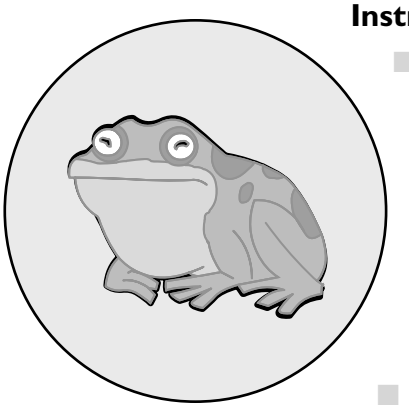
Rabbit - Mexico

Woman - Polynesia



Boy & Girl - Scandinavia

This activity can be done individually or as a family



Instructions

- Take a look at the character(s) from one of the cultures above that is shown on the story sheet on your table. In each case, the storyteller used the light and dark spots on the face of the Full Moon to create the character(s) in their story. Read the story together as a family
  - Look at the image of the Full Moon on your table.
  - Outline a character or characters that **you see** when you look at the Moon.
- Write your own story about how the character(s) got there.

From the Family ASTRO Moon Mission Kit

Fox – A Story from Peru

All Fox could think about was getting to Moon. After braiding a grass rope long enough to reach Moon, he got help from the birds to fly it up to Moon for him. Once that was done, Fox climbed up the rope. The birds say they can see Fox in the Full Moon. Can you?

From the Family ASTRO Moon Mission Kit

www.astrosociety.org/education.html

Moon Woman – A Story from the Maori of New Zealand

The woman in the Moon is named Rona. She was returning one moonlit night from a stream with a calabash full of water. Moon slipped behind a cloud for a moment, and in the darkness Rona stumbled on the root of a tree. Angry, she cursed Moon. Moon, who would not stand for this abuse, swooped down on her and carried her off along with her water gourd and the tree that had tripped her. The Maori still see all three there today. Can you?

From the Family ASTRO Moon Mission Kit

www.astrosociety.org/education.html

Man in the Moon – A Story from Australia

Back in the Dreamtime, Baloo (Moon) visited the Earth and saw two young ladies who invited him to ride in their canoe. He was unsteady in the little craft and fell into the water. Embarrassed by his clumsiness he hid. Although he now shines brightly every month, he also remembers this little accident and shrinks away to gather his courage. Can you find the embarrassed Baloo in the face of the Full Moon?

From the Family ASTRO Moon Mission Kit

The Toad in the Moon – A Story from China

Heng O found out that her husband, Sheng I, had the secret of immortality. When she found the potion, she drank it and immediately flew out the window up to Moon. Sheng I was so angry with what she had done, he turned her into a three-legged toad. Can you see the toad in the face of the Full Moon?

From the Family ASTRO Moon Mission Kit

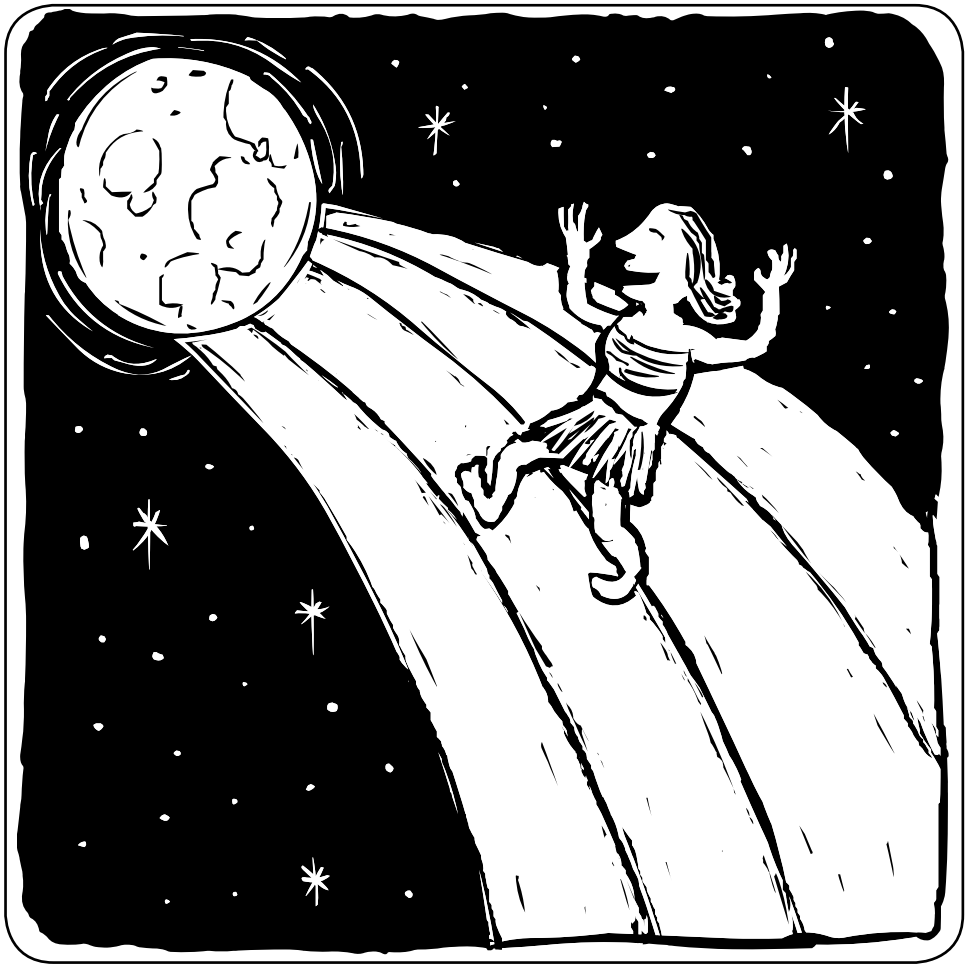
Rabbit Moon – A Story from the Aztecs of Mexico

In ancient times, a god chose to set himself on fire and jump into the sky to light the cold, dark world. He became the Sun. A second god, jealous of the praise that this new Sun was getting, did the same. This was too much light and another angry god threw a rabbit at the second Sun's face to dim his light, making him Moon. Can you see the dark rabbit on the Moon?

From the Family ASTRO Moon Mission Kit

www.astrosociety.org/education.html

Moon Woman – A Story from Polynesia



Have you ever seen a rainbow at night formed by moonlight instead of sunlight? Legend has it that Hina, a Polynesian woman, who was on her way to get some fresh water, did. She had always wanted to live in the heavens, so she walked along the rainbow and didn't stop until she reached Moon. She lives there now and can be seen beating her tapa board to make cloth. Can you find her?

From the Family ASTRO Moon Mission Kit

www.astrosociety.org/education.html

Jack and Jill – A Story from Scandinavia

Hyuki (Jack) and Bil (Jill) were sent up the hill to fetch a pail of water from a magical well. Water from this well inspired poetry and prophecy. The children were spotted by the man who carries Moon across the sky each night in his chariot. He scooped them up into his chariot and carried them away. The two children can still be seen there today, bucket, pole and all. Can you find the splash from the spilled bucket?

From the Family ASTRO Moon Mission Kit

www.astrosociety.org/education.html

What do you see in the Moon? Create one or more characters and tell the story.

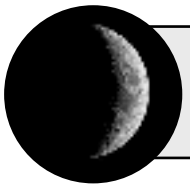
Character(s):

Story:

Our Changing Moon

by Dennis Schatz *(Pacific Science Center)*

An Activity for the Whole Family from Project ASTRO



- **Type of Activity:** Station and Facilitated
- **Set up Time:** 15 minutes
- **Time to Do:** 7-8 minutes for station, 20 minutes for facilitated

What's This About?

Although we see them all the time, the phases of the Moon seem mysterious and confusing to many people. In this activity, families will get a chance to challenge their preconceived notions about what causes the phases of the Moon. Using pictures of the Moon in different phases and Styrofoam balls to model the phases, families will have a chance to discover what makes the Moon look different from day to day.

Materials Included

- Our Changing Moon Family Worksheet. Make one copy for each family for part one, and one copy for part two (page 33).
- 20 Styrofoam balls. The goal is one for each family member. We purchased ours at: Molecular Model Enterprises (608) 884-9877.
- Full Moon Map. Make one copy for each family for part two (page 35).
- Moon phase transparencies

Materials You'll Need to Get

- Pair of scissors for each family
- One sheet of scratch paper per family
- Scotch tape or glue sticks
- Working light bulb (e.g., table lamp with shade removed)
- Extension cord
- Room that can be fully darkened
- Overhead projector and screen (optional)
- A pencil for each family member (to put Styrofoam balls on)

Setting up the Activity

Put a copy of the Family Worksheet (page 33) and Full Moon Map (page 35) on each family table. Make sure each family has a pencil, pair of scissors, glue or tape, and scrap paper at their working area. The rest of the materials will be passed out as they are needed.

It is important that the room in which you do this activity can be quite dark. Close blinds, tape the edges of curtains to walls, cover windows with black paper and take any other appropriate steps to make the room as dark as possible when lights are turned off. Put your light bulb on a table or desk at the front or center of the room.

Part One: Doing the Station Activity

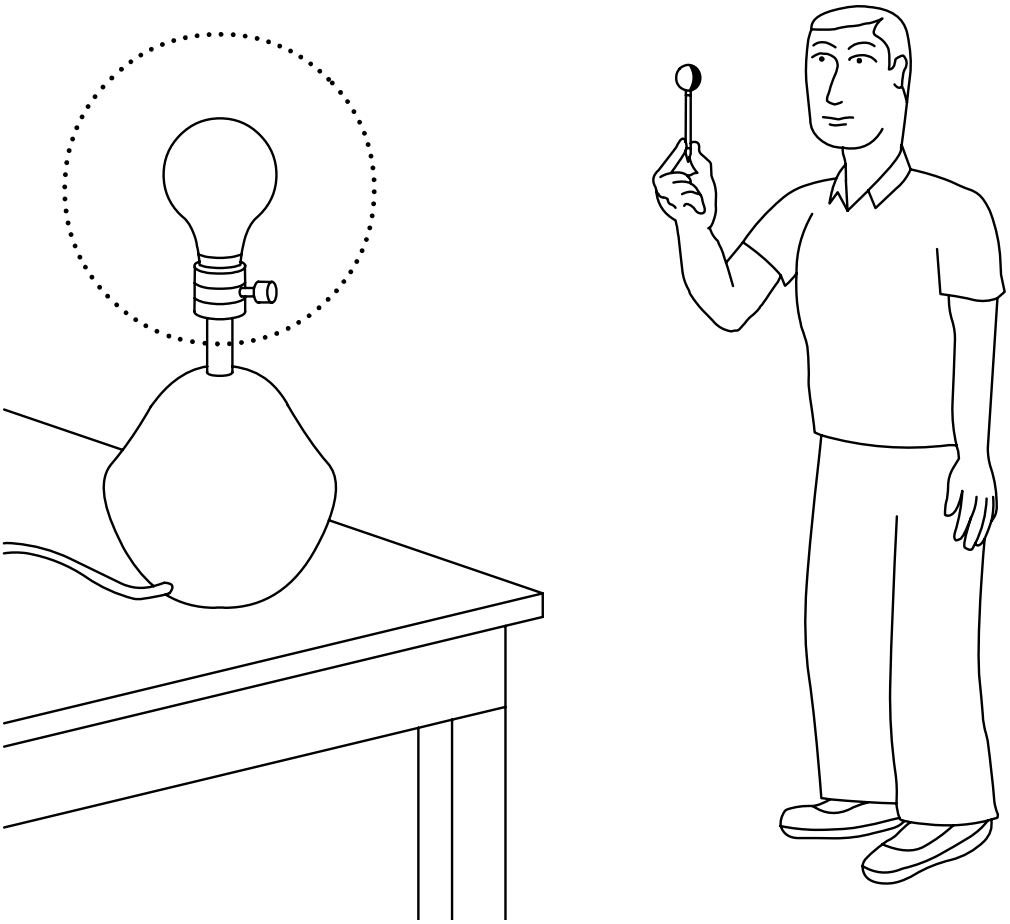
Because this is a fairly lengthy activity, we suggest that the first part be done as a station. Make clear to families as they enter that they should all take time to do this station. The question being explored is, "What causes the phases of the Moon?"

- Each family's set of instructions asks them to cut out the set of six lunar photos and put them in the order that they would see them if they went out during the next few weeks.
- Give them time to do the ordering while you circulate around the room asking questions and providing clarification.
- Remind groups to tape/glue the photos on to a scratch piece of paper, being sure to number them and indicating which way is up.

Part Two: Doing the Facilitated Activity

- Allow families to circulate around the room and see what other groups predicted.
- Welcome any insights or observations they made.
- Given the families' different knowledge of lunar phases, there are several reasonable ways to order the photos. Tell them that they may be able to improve on their predictions by understanding what causes the phases of the Moon.
- Tell them that they are now going to make a model of the Earth, Moon and Sun that will show them what causes the phases.

- Darken the room and turn on the light bulb at the front or center of the room. Point out that the light bulb represents the Sun. Ask them to stand so they can use their heads as the Earth. Point out what part of their head is the poles, and that their eyes are their present location on the Earth (e.g. San Francisco, Chicago, etc.).
- Provide each family member with a Styrofoam ball to be the Moon. Have them put a pencil in the hole in the ball and hold the ball by the pencil at arm's length towards the Sun (the "starting position").

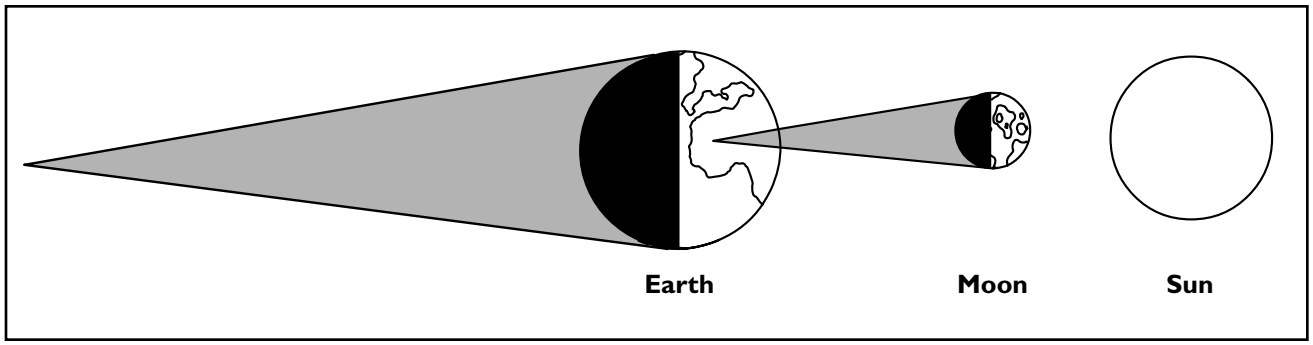


- Demonstrate how the Moon goes around (orbits) the Earth in a counterclockwise direction (i.e. your right shoulder circles forward toward your left shoulder) every 29 1/2 days.
- Ask them to discuss what might cause the phases that we see on the Moon. Arrive at the idea that the phase of the Moon is determined by where the Moon is in its orbit relative to the Earth and Sun.
- Allow the families to demonstrate this themselves by having them begin in the starting position (with the Moon toward the Sun), and then watch the phases on the Moon as they slowly move the Moon in its orbit while slowly turning themselves around as the Earth on its axis does. Allow them sufficient time to explore this. Suggest they look at the phases seen in the lunar photos and determine where the Moon has to be in its orbit (relative to the Earth and Sun) to produce each phase. If needed, you can show one of the photos on the overhead projector and ask them to demonstrate where the Moon must be in its orbit to produce that phase.
- Once they have had sufficient time to explore, ask a volunteer to summarize what they observed as they moved the Moon in its orbit. For example, the Moon is dark (New) when in the direction of the Sun; as the Moon moves away from the direction of the Sun they begin to see a thin crescent that is on the right side of the Moon; the crescent gets bigger as the Moon gets farther away from the direction of the Sun until it becomes a First Quarter Moon about seven days later; etc.

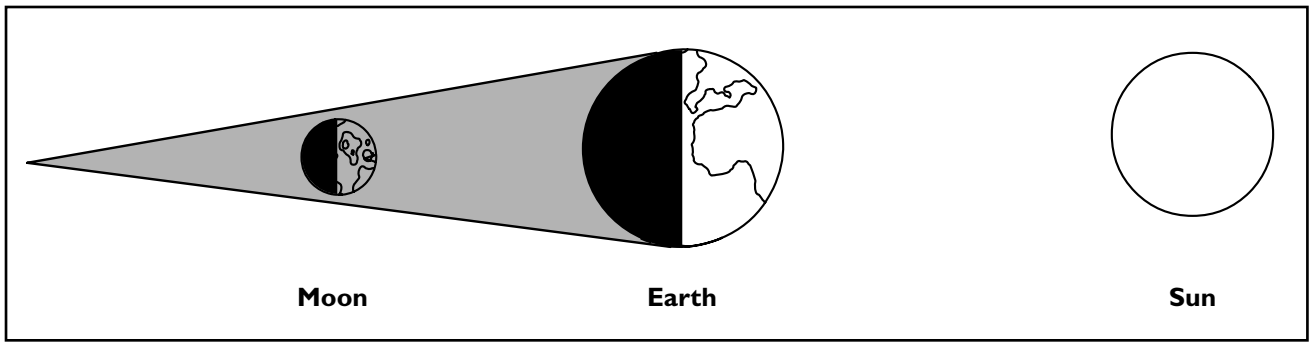
- At this stage you may want to clarify that the Moon does not orbit the Earth once a day. The daily rising and setting of the Moon and its daily motion across the sky are a consequence of the spin of the Earth on its axis. But the Moon makes only a small change in its phase (appearance) each day because it takes 29 1/2 days to orbit the Earth, and thus its position relative to the Sun and Earth has changed relatively little in a day.
- Tell them that now that they have a better understanding of what causes the phases of the Moon, you are going to ask them to take a second look at their set of six lunar photos and order them based on their new understanding of lunar phases. Tell them that you are also going to give them a second sheet of phases and encourage them to use the map of the Full Moon this time around to help them orient the photos (e.g. tell which way is up and down).
- Give them time to re-order the phases and tape/glue them down.
- If there is time, invite the groups to look at other families' work.
- If you have enough time and an overhead projector, summarize what they discovered during the activity using the transparency of the set of six lunar photos (provided in your Leader Kit).

Family Challenge: What phase must the Moon be in to produce lunar and solar eclipses

If time permits, discuss lunar and solar eclipses with the families. Chances are they were challenged not to make an eclipse as they were modeling Moon phases (i.e., each time they got close to a full phase, they would have to raise their balls to keep them illuminated). After their experience with the phase activity, ask them what phases the Moon must be in to produce lunar and solar eclipses. You may first need them to define what is meant by a lunar and solar eclipse and then give them some time to explore moving their model Moons in orbit to produce both types of eclipses.



Solar eclipse (not to scale)

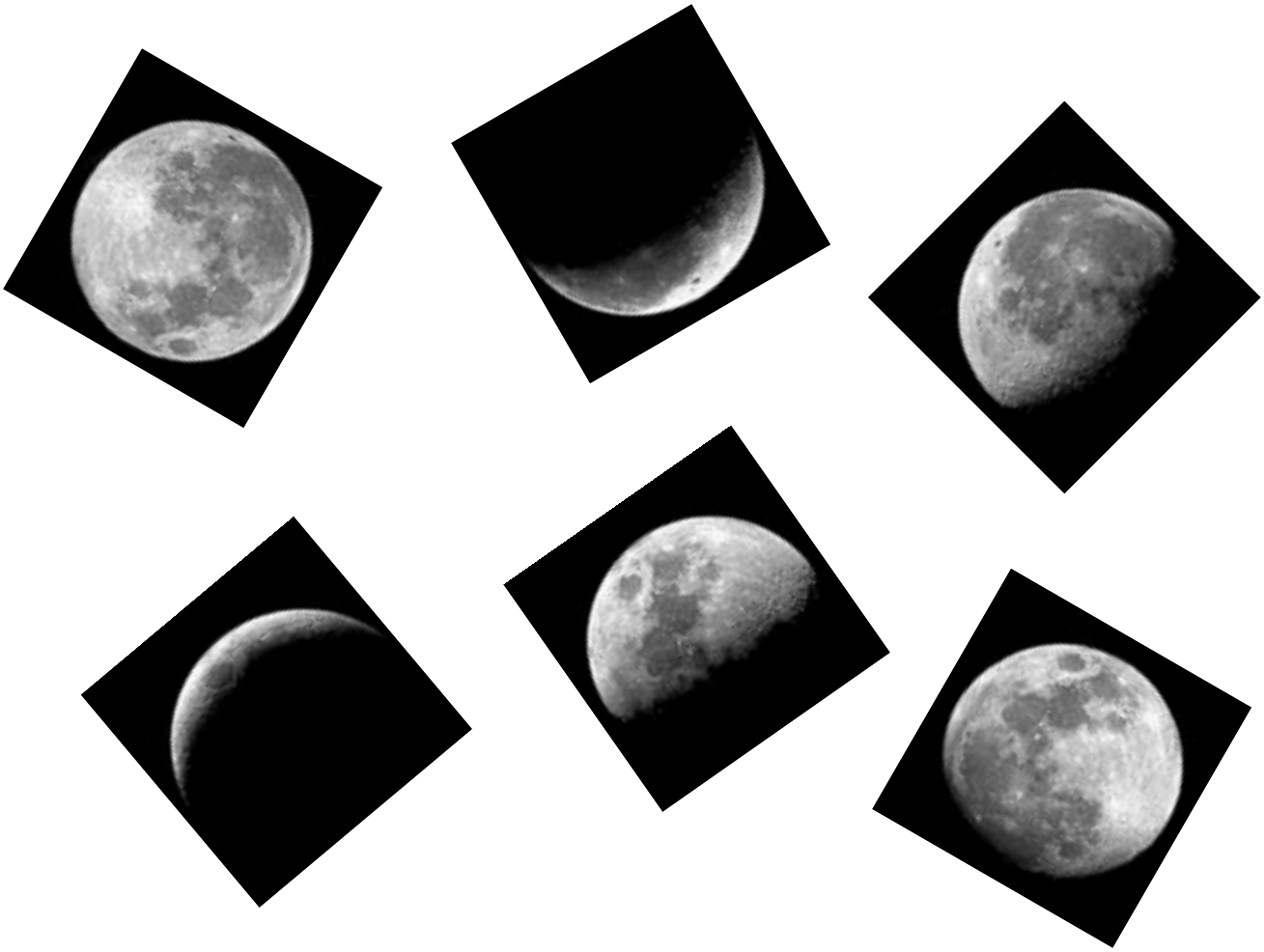


Lunar eclipse (not to scale)

Our Changing Moon Family Worksheet

BY DENNIS SCHATZ *(Pacific Science Center)*

An Activity for the Whole Family from Project ASTRO

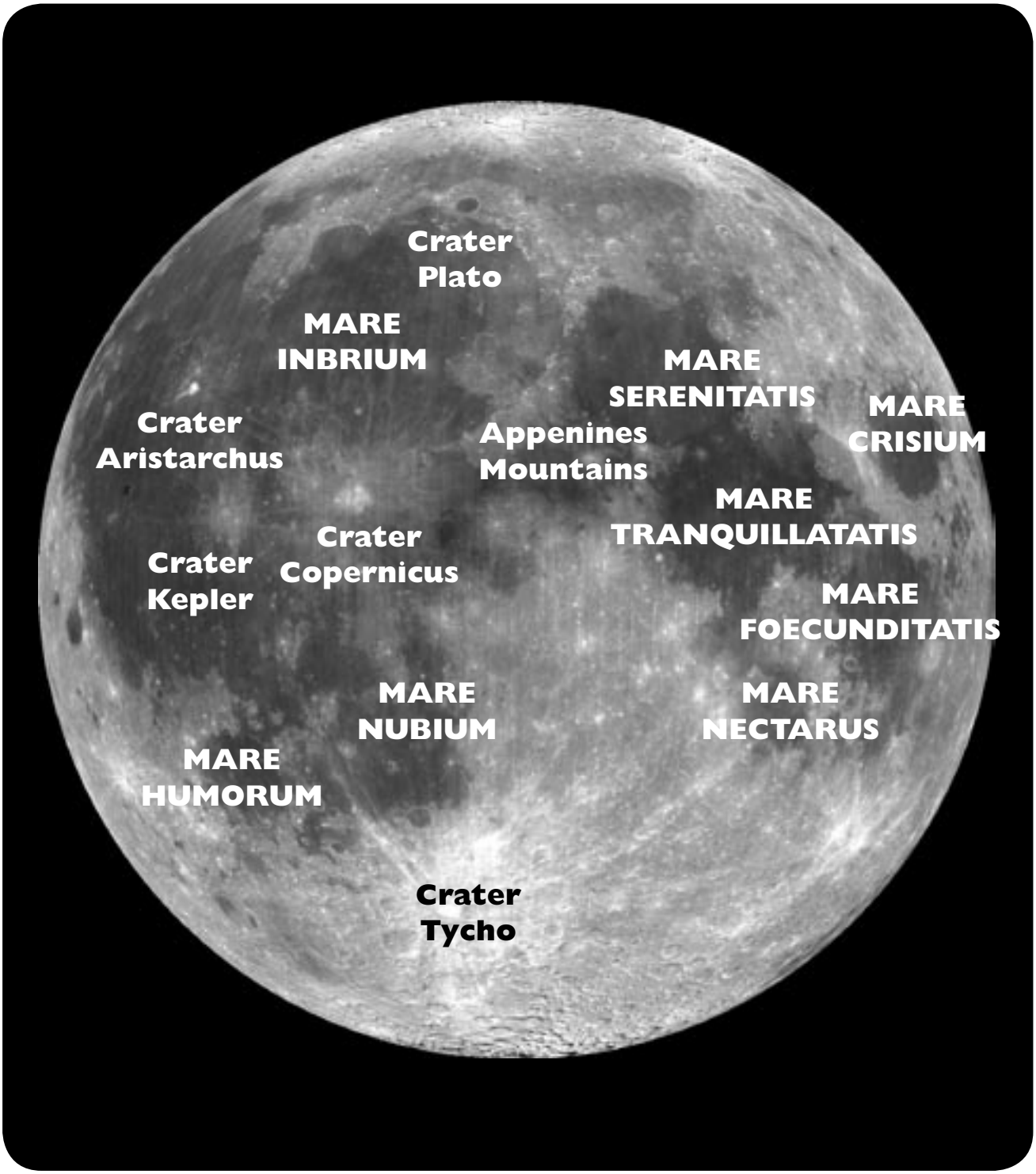


Instructions

■ Cut out the set of six lunar photos above. Arrange them in order of how you would see them if you went out during the next few weeks.

■ Once you've settled on an order, tape/glue the photos on to a scratch piece of paper, being sure to number them and indicate which way is up.

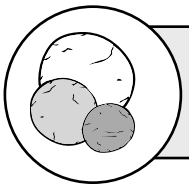
■ Keep them handy, we'll check your answers after we do a different Moon phase activity.



Sizing up the Moon

by Dennis Schatz *(Pacific Science Center)*

An Activity for the Whole Family from Project ASTRO



- **Type of Activity:** Facilitated
- **Time to Do:** 20 minutes
- **Set up Time:** 5 minutes (not including time to make playdough)

What's This About?

This activity starts by asking for participants' ideas about the relative sizes and separation between the Earth and Moon. It builds from these initial thoughts to help them produce a model of the Earth and Moon that provides the accurate relative sizes, as well as the appropriate distance between them.

Materials Included

- Sizing up the Moon Family Instructions master (page 41)
- Earth/Moon location sheet masters (page 43)

Materials You'll Need to Get

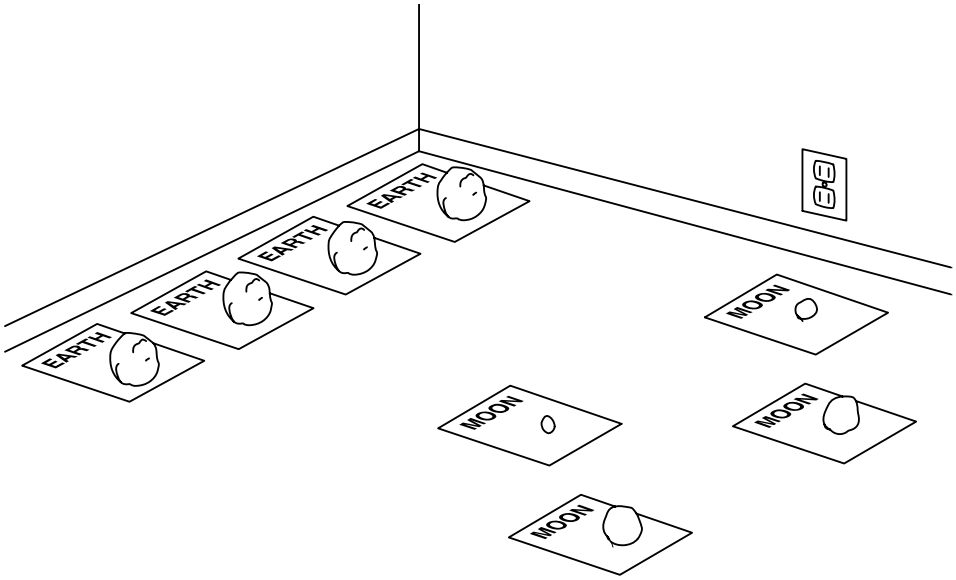
- Three-inch diameter ball of playdough (approximately 1 pound) for each family and one ball for the facilitator
- One copy of each master for each family. Cut location sheet (page 43) in half.
- 5 plastic knives
- Cutting board or sheet of wax paper for each family
- A piece of string 7.5 feet long, which represents the distance between the Earth and Moon at the scale used in this activity (3″ x 30 Earth diameters = 90″ or 7.5 feet)

Setting up the Activity

Place the playdough balls on each family's table with the instruction sheet (page 41) and the two half-page location sheets (page 43) when you are ready to begin. Please note: Do not pass out playdough early, it will be a distraction.

Doing the Activity

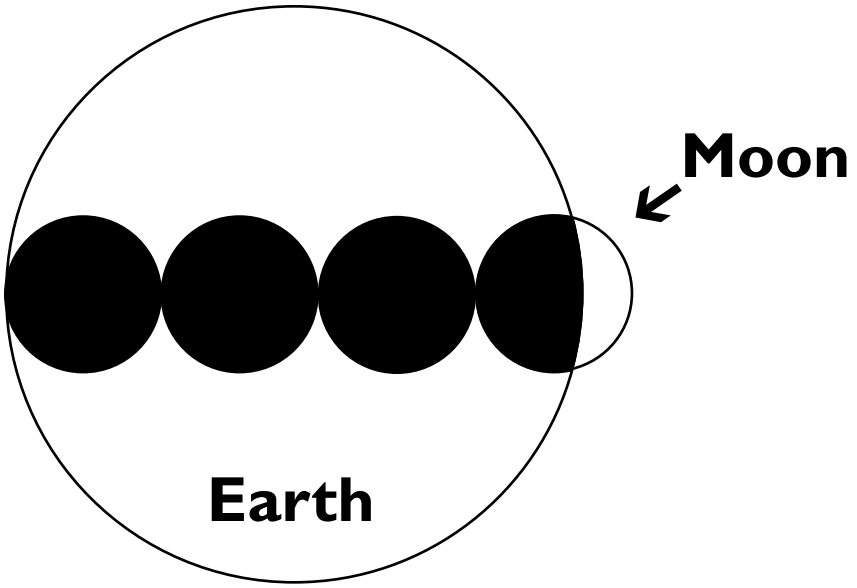
- The first step for families is to make a prediction regarding how much of the playdough ball would go into producing a model of the Earth and how much would go into a model of the Moon (at the same scale)? Then ask them how far apart the model Earth and model Moon would be? Tell them where in the front of the room you want them to put their Earth models so there is also room to place the Moon models at the correct scaled distance. Be sure they put their family names on both the Moon and Earth location sheets.
- After all families have made their predictions, you are now ready to start discussing the differences and similarities in their predictions. Ask who is willing to share why they chose the sizes and distance in their model Earth and Moon. Conclude the discussion by asking if anyone now wants to modify a prediction. If there is time, you can let them physically make the changes. Otherwise, just accept the verbal description of what changes they would make.



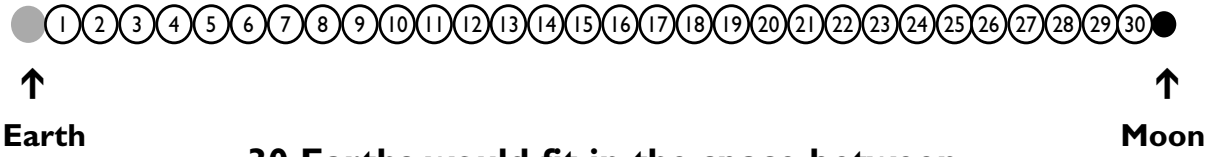
- Tell them that you are now going to make a model together that shows the accurate comparison of sizes and distance. You will need 5 volunteers (preferably from different families).
- Divide your playdough ball into 5 equal pieces (this is the facilitator's ball). Give each volunteer one piece and a plastic knife and ask them to cut it into 10 equal pieces. When they are done, have them bring back their pieces.
- Ask for another volunteer to help you pick an "average" size piece out of the 50 that are now in front of you. Set the "average" piece aside.
- Point out how many are left. Have yet another volunteer roll the 49 pieces back together. Now you have accurate Earth (larger ball) and Moon (smaller ball) scale models.
- Ask them for any comments that they care to make about their predictions vs. the actual relative sizes.
- Now place your model Earth next to the other Earth models in the front of the room. Ask two volunteers to help determine the correct distance to the Moon. One volunteer holds the accurate model Moon, while the other person takes one end of the string. You hold one end of the string at the model Earth while the two of them walk away from the Earth. When they reach the end of the string, they should hold the model Moon up in the air at the end of the string.

- The families can now compare the correct scale distance to the model Moon to their various predictions. Ask them for any comments that they wish to make about their predictions vs. the actual distance in the scale model.
- This is now a good time to talk about the real sizes for the Earth and Moon, and how far apart they are:

  Earth's Diameter = 12,756 km (7,926 mi)
  Moon's Diameter = 3,476 km (2,160 mi)
  Distance from Earth to Moon = 384,000 km (239,000 mi)



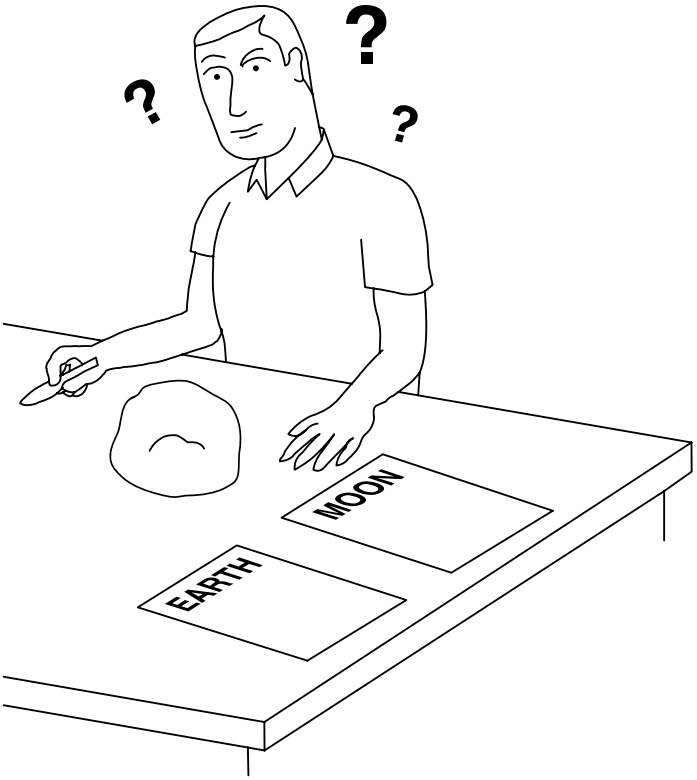
3.7 x diameter of Moon = diameter of one Earth



30 Earths would fit in the space between the Earth and Moon

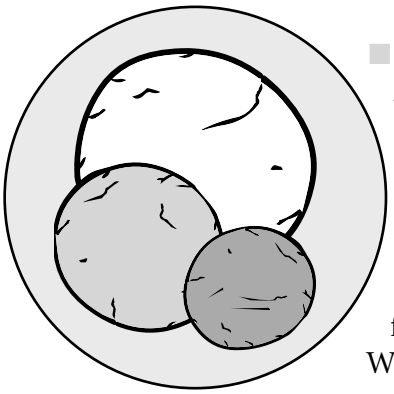
- This is also a time when you might discuss the time it takes light to travel to the Moon from Earth, or how long it took the Apollo spacecraft to take the astronauts to the Moon. Light takes 1.3 seconds to get to the Moon from Earth and another 1.3 seconds to get back. That's why there was a slight delay between questions and responses when astronauts on the Moon communicated with Earth. It took the Apollo 11 astronauts about 73 hours and 27 minutes to travel from Earth's orbit to an orbit around the Moon. To put it in perspective, you might ask how long they think it would take them to drive to the Moon in their family car, if they could maintain a highway speed of 70 miles/hour (239,000 miles/70 miles/hour = 3,414 hours = 142 days = almost five months — and that's DRIVING NONSTOP, with no bathroom or sleeping breaks!).

Sizing up the Moon



Instructions

- Divide your playdough ball into two balls so that one ball is what you think is the right scale to represent the Earth and the other the Moon.



- Place your model Earth on the sheet of paper labeled *Location of Model Earth* and write your family name on that sheet. Place the model Earth and sheet at the front of the room (as directed by your leader).

- Think about how far away the model Moon would be at this scale. Place your model Moon on the sheet of paper labeled *Location of Model Moon* at an appropriate spot inside (or outside) the room (away from your model Earth) to represent the scaled distance to the Moon. Write your family name on that sheet too.

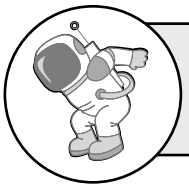
Name: _____

Name: _____

Moon Jump

by Suzanne Chippindale

An Activity for the Whole Family from Project ASTRO



- **Type of Activity:** Facilitated
- **Time to Do:** 20 minutes
- **Set up Time:** 2 minutes

What's This About?

In this activity families will discover one of the effects of lower gravity. After measuring how high they can jump on the Earth, they calculate how high the equivalent effort would take them on the Moon.

Materials Included

- Moon Jump family handout master (page 49)

Materials You'll Need to Get

- Colored markers, 2-3 per family
- Measuring sticks or tape, one per family
- Pencils
- Calculators (optional)
- One copy of the Family Instructions per family (page 49)
- 2-3 sheets of flip chart (or equivalent, e.g., butcher) paper (27″ x 34″) per family
- Masking tape
- Stool or stepladder (for taping paper high up on wall)

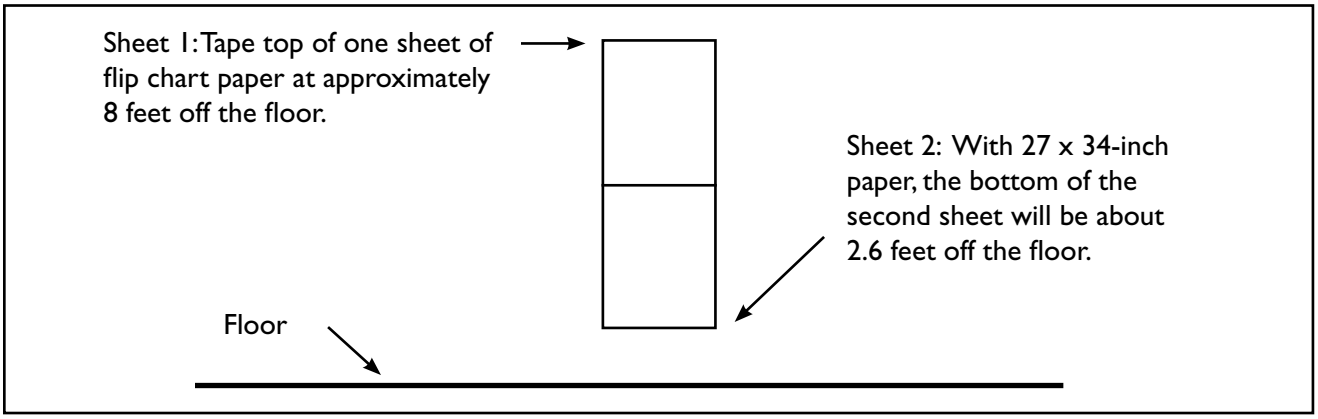
Setting up the Activity

- Tape at least two sheets of flip chart (or equivalent) paper (27 x 34 inches[1]) per family (including a set for yourself for demonstration purposes) at different locations around the room (jumping stations[2]). A good average height for **the top** of the highest sheet (the adult sheet) is eight feet, so you'll probably need a stool or short ladder to get it up that high on the wall. The second sheet, to accomodate jumping kids (*and short adults!*), should go immediately underneath. In some cases, to get the full range for some families, you may need a third sheet (so have extra sheets on hand just in case). The figure on page 46 shows a typical jumping station.

Footnotes:

[1] Note that when you tear off a sheet of 27 x 34-inch flip chart paper from the pad, the actual height of the paper is approximately 32.5 inches (2.7 feet).

[2] You can also have the families set these up themselves, just before they start jumping.



- Set a measuring stick (yardstick, measuring tape, etc.) at each jumping station.
- Don't pass out markers or instructions until after your initial demonstration (see *Doing the Activity* below).

Suggestions for Introducing the Activity

This is an opportunity to discuss gravity, which is not a simple concept for many to grasp. Start by asking if anyone knows what gravity is. After getting around to a working definition like, "What pulls you back to Earth when you jump up?", ask families, "What is the gravity on the Moon like compared to Earth's — stronger or weaker?" Unless you have older students, many will not know what gravity depends on, so you can introduce the ideas of 1) mass; and 2) distance from the center of mass. A brief overview of this is included in the background information below. After talking about the differences and how much weaker the Moon's gravity is (1/6 of the Earth's), demonstrate the activity.

Doing the Activity

Begin with a demonstration:

- Grab a marker.
- Face the flip chart paper taped to the wall; then stand flat-footed and stretch your arm above your head and make a mark on the paper with your marker.
- Next, because running starts are not allowed (they alter calculations), take a small step back to give your knees room to bend. Now jump as high as you can, tapping the paper with your marker to make another mark.
- Using a yardstick (or equivalent), measure from the top mark to the bottom one.
- Record the measurement. That's how high you can jump on Earth.
- Now multiply your Earth jump by six. That's how high you can jump on the Moon. Convert that number to feet and inches (as often this is more meaningful to families than just inches). Make the point that it is the bottom of your feet that would be that high off the ground if you were jumping on the Moon and mark that distance from the floor on the paper to highlight the fact.
- Next, ask families to choose roles as listed on the Family Instructions. Emphasize that they will rotate jobs so that everyone has a chance to jump.

- Issue markers and instructions to each family and point out the various jumping stations around the room (or have families set them up).
- Circulate around the room making sure everyone is jumping, marking, and calculating correctly.
- When the group is done, compare some results. Could anyone jump over their own height on the Moon? Who jumped the highest? Have a closing discussion on what it would be like to walk on the Moon or how various sports would have to be changed to play on the Moon. What, for example, would it be like to play basketball? How high should the hoop be?
- When done, you can let your families take the marked sheets of flip chart paper home with them as a souvenir.

This Concludes Session 1 of the Moon Mission Family Event

(See sample agendas, pages 6 and 7)

Background Information on Gravity

Why is gravity on the Moon different?

The pull of gravity on the Moon is less than on Earth. The gravity you feel depends on two things:

1) the mass of the body pulling on you (the amount of material that makes it up), and
2) your distance from the center of the body.

Both are different on the Moon:

1) The Moon has less mass than our planet:

Mass of Earth: 5.98 x 10^{24} kg, that's 5,980,000,000,000,000,000,000,000 kg
Mass of Moon: 7.23 x 10^{22} kg, or 72,300,000,000,000,000,000,000 kg

So, the Moon has 81 times less mass than Earth.

2) The Moon is smaller, and so you are closer to its center when you stand on its surface.

Size of Earth (radius) = 6,378 km
Size of Moon (radius) = 1,738 km

So on the surface of the Moon, you are 3.7 times closer to the center of gravity than on the surface of the Earth.

Combine these factors the right way* and you find that:

Gravity on the Surface of the Moon = 1/6 Gravity on the Surface of the Earth

*Surface gravity depends on the mass and inversely on the radius squared:

$$(g_M/g_E) = M_M/M_E = \frac{(1/81)}{(1/3.7)^2} = 0.0123/0.0730 = 1/6$$

When you jump, gravity pulls you down. So if you could jump on the Moon, you would be 1/6th as heavy but have the same strength in your legs, and thus, could jump 6 times as high as you can on Earth.

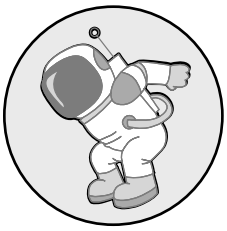
Why hop?

Apollo astronauts weighed over 300 pounds on Earth when fully suited. And although that would be just over 50 pounds on the Moon, it's still a lot of bulk to maneuver with while walking. So hopping made the task of getting around much easier. But the astronauts purposefully took only small hops. Wearing a lunar space-suit is a bit like carrying another person on your back. Even if you can lift someone to give them a piggy-back ride, try stopping quickly or changing direction while running with them. Their additional inertia will tend to keep you moving forwards in the same direction, and it will be much harder to stop once you get going. Even though your rider (or space-suit) weighs less on the Moon, this resistance to changes in motion (called "inertia") will be the same. Thus if one wants to maneuver well on the Moon, it's best to make "baby hops" even if you can manage leaps and bounds! The astronauts also kept their movements to little bunny hops for safety reasons. With all of that bulk added to a fall, it simply wouldn't be safe — and the nearest doctor was 250,000 miles away. So, although they may have looked humorous hopping across the surface of the Moon, baby hops were simply the easiest and safest way to get around.

Moon Jump

BY SUZANNE CHIPPINDALE

390 Ashton Ave., San Francisco, CA 94112 ■ www.astrosociety.org/education.html



To Begin

Assign each member of the group one of the following tasks. After the first jump, rotate jobs so everyone has a turn to jump.

1 Jumper

Your job is to jump as high as you can.

- Grab a marker.
- Stretch your arm high over your head with your feet flat on the floor. Make a mark on the paper on the wall. This will be your "standing mark".
- Now jump and mark as high on the paper as you can (no running starts). This is your "jumping mark".

2 Measurer

With the yardstick (or equivalent) provided, measure the separation between the two marks. Call out the number to the Recorder.

3 Recorder

Record below the number that the Measurer gives you beside the name of the Jumper. This is how high he/she can jump on Earth. Multiply this number by 6 to find out how high the Jumper could jump on the Moon.

And Now…

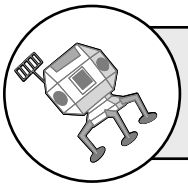
Switch jobs until everyone has a chance to be the Jumper.

Jumper	Distance Between Jumping and Standing Marks		Distance Jumped On Moon
		x 6 =	
		x 6 =	
		x 6 =	
		x 6 =	

Crash Landing!

Adapted by Suzanne Chippindale from *The Space Age Activity Guide,* © 1992 QED Communications Inc., and several earlier NASA sources.

An Activity for the Whole Family from Project ASTRO



- **Type of Activity:** Station and Facilitated
- **Set up Time:** 2 minutes
- **Time to Do:** 15 minutes for stations, 15 minutes for facilitated debrief

What's This About?

In this activity we want families to start thinking about the Moon as a place and not a "nightlight". There are no right answers to the challenge, although some answers are better than others. The activity gets families to talk about the environment on the Moon so they can determine what they would need for survival on the lunar surface. Families pick and sort items (from a list provided) into those they want to keep or discard to help them survive a crash landing on the Moon. Teamwork is essential in this activity since different members of the family may know different things about either the Moon or general science. By pooling their knowledge, families are more likely to come up with good answers.

Materials Included

- Crash Landing! family handouts, pages 53-61

Materials You'll Need to Get

- Scissors, 1 per family
- Tape or glue sticks, 1 per family
- Flip chart and markers, blackboard and chalk, or whiteboard and dry erase markers

Setting up the Activity

Make copies of the family handouts and put one set on each family table (one set per family). Make sure each family table also has a pair of scissors and tape/glue sticks.

Doing the Station Activity

The initial cutting and sorting is done as a station activity and needs no verbal introduction beyond calling the materials to the attention of the families. The debriefing, however, can be extensive.

Doing the Facilitated Activity

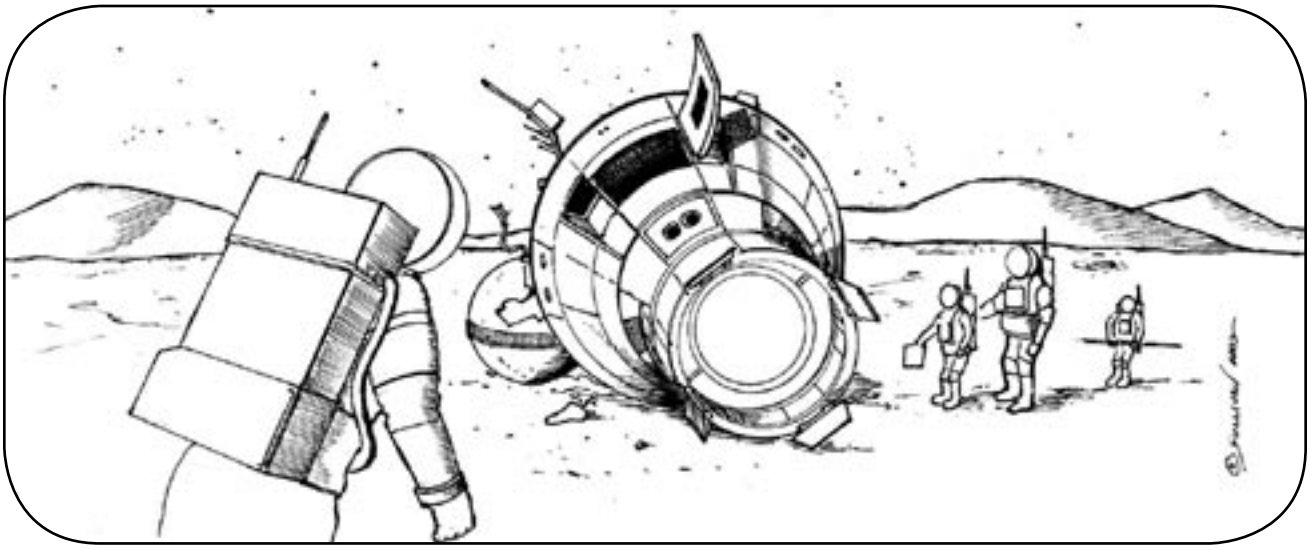
- Open with a group discussion about what people already know about the Moon. Parents might remember the Apollo program as a part of their personal history, so ask them to share brief accounts of what they remember.
- Read the scenario aloud on the first family handout (page 53) and ask families to give you the top 5 items that they kept. Record the answers on a flip chart (or equivalent) at the front of the room.
- Debrief the list by asking for each family's justification. Move down the list asking about each item. At this point, you can use the NASA engineer's answers below for comparison, if you wish, but emphasize that there are no right or wrong answers and that there might be some unorthodox and clever uses for some of the items.

Background Information: What a NASA Engineer Might Say

Item (Ranking)		Explanation
Oxygen (1)	Keep	The most pressing survival requirement
Water (2)	Keep	For replacement of tremendous liquid loss on the side of the Moon exposed to sunlight
Constellation Map (3)	Keep	Primary means of navigation; stars are visible if you look away from the Sun in the sky
Food (4)	Keep	Efficient means of supplying energy requirements
FM transceiver (5)	Keep	For communication with any rescue ship on line of sight
Rope (6)	Keep	Useful in scaling cliffs or use in case of emergency
First aid kit(7)	Keep	Needles for medicines and vitamins fit special aperture on suit
Raft (8)	Leave	Low priority; but carbon dioxide bottle possible propulsion source
Flares (9)	Leave	Low priority; possible distress signal when rescue ship is sighted
Heater (10)	Leave	Not needed unless on dark side
Compass (11)	Leave	Useless; Moon has no global magnetic field
Matches (12)	Leave	No air on Moon, so matches will not burn

Crash Landing!

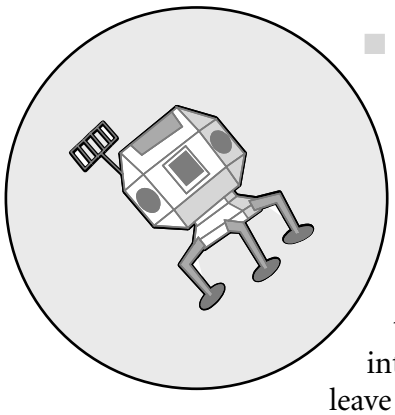
Adapted by Suzanne Chippindale from *The Space Age Activity Guide,* ©1992 QED Communications Inc., and several earlier NASA sources



Imagine a time in the future when there are lunar bases. People are living and working on the Moon, exploring and learning about it, and doing other kinds of research that can't be done on Earth.

An accident occurs on a routine journey from Earth to a lunar base. Something has gone wrong and you crash land on the Moon's surface sixty miles from the nearest base. At the crash site it is daylight on the Moon and will be for the next few days. In the Moon's lower gravity, sixty miles is not too far to walk, but you are limited in what you can carry. What should you take with you?

Your Mission:

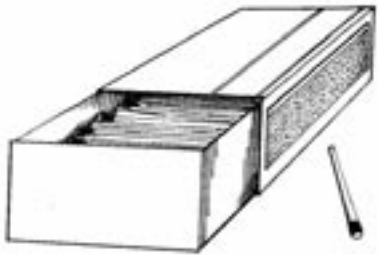


- Cut out the list of items on the next two sheets.
- Sort them into 2 groups: items you would take with you and things you would leave behind.
- Put the ones you would take with you in order of usefulness, from "essential for survival" to "not so important".
- Once you've come to an agreement within your group, use glue or tape to attach all items to the last two sheets provided. Separate items into the ones you would take (in priority order) and the ones you would leave behind.

Crash Landing!

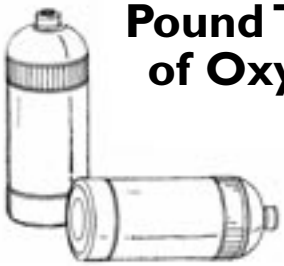
List of recovered items to cut out

Box of Matches



These might be useful to make a signal fire or camp fire in case of a crash on Earth, but would they be useful on the Moon?

Two 100 Pound Tanks of Oxygen



These tanks would weigh 100 pounds on Earth, but in the Moon's lighter gravity, they would weigh less than 17 pounds each.

Magnetic Compass

True North on Earth varies from magnetic North by as much as 23 degrees. How well could you navigate on the Moon with this?

Food Concentrate

Astronaut food is notoriously bad, but light weight and compact. Just add water and that bowl of mush could taste like a pot roast.

Self-Igniting Signal Flare

This flare could work underwater or in the vacuum of space.

Solar-Powered FM Transceiver

This radio transmitter and receiver requires only sunlight to function properly.

Crash Landing!

List of recovered items to cut out

50 Feet of Nylon Rope

Nylon rope is tough and light weight.

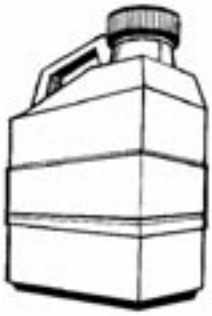
Moon Constellation Map

Navigating by the stars on the Moon would be very much the same as navigating by the stars on Earth.

Portable Heating Unit

This unit is designed to work on its own batteries with no external power source.

5 Gallons of Water



Water is essential to life and to reconstituting dehydrated food

First Aid Kit with Hypodermic Needles

Hypodermic needles fit special openings in the standard issue space suit.

Self-inflating Life Raft that uses a Carbon Dioxide Canister

This raft is standard issue on shuttles that land on Earth, in case of an emergency water landing.

Crash Landing!

Items to Keep (not necessarily 6; keep as many or as few as you would find useful.)

Crash Landing!

Items to Leave (not necessarily 6; leave as many or as few as you would not find useful.)

Moon Mission Game: An Overview

An Activity for the Whole Family from Project ASTRO

- **Type of Activity:** Facilitated and Take-Home
- **Set up Time:** 2 minutes
- **Time to Do:** 10 minutes for intro, 30-40 minutes to play (at event)

What's This About?

Moon Mission is a cooperative strategy game. Family members must work together as a team in a race against the setting Sun. Their aim is to devise a joint strategy to recover as many damaged instruments as they can from around the surface of the Moon while making sure they leave no one stranded in the dark. If anyone is left behind after 15 Earth days, the whole team loses. The more instruments they recover, the higher their team ranking. It is not just a strategy game though; families will learn about the lunar environment as they pick event cards and have to live with the consequences of being on the Moon.

Materials Included

- One sample copy of the *Moon Mission* game

Materials You'll Need to Get

- Additional copies of the *Moon Mission* game, one for each family

Introducing the Game

If you have used the Crash Landing! activity at your event (see page 51), the *Moon Mission* board game is a natural to end with since families have been introduced to what it is like on the lunar surface. You may want to talk a bit about meteoroids — chunks of rock or ice that hit the surface of the Moon (since they play a role in setting up the story of the game.) On Earth, smaller chunks typically burn up due to friction with the Earth's atmosphere, but in the airless lunar environment, every chunk reaches the surface.

Open the sample game from your Leader Kit to show families each of the playing pieces and basic set up. Emphasize that this is a cooperative game. Players don't compete against each other, but work together in a race against time. Read the two paragraphs in the instructions, under the heading "The Mission" (see below), to families as you distribute the games.

The most challenging concept in this game is how the passage of time is counted. Time is marked using the Moon phases as a counter. The Moon phase counter shows what the Moon would look like from Earth, but the game is played on the surface of the Moon. So it would be good to go over the two perspectives with the families before they go home. The Moon keeps the same side always facing the Earth and it takes 29 and 1/2 days to complete a phase cycle (for the Moon to return to the same position in space relative to the Sun). This means that the Sun is up for nearly 15 Earth days and absent for 15 days as seen from any point on the surface of the Moon.

Doing the Activity

First and foremost, it is extremely important that you try playing the game first with your own family and/or friends **before** leading your first event. Also, visit the *Moon Mission* web site at: **http://www.astrosociety.org/education/family/resources/moon.html.**

Have families play the game for up to 40 minutes before they take it home so they have a chance to ask questions.

The Mission (to be read to families before they start playing)

The Time is the Future. You are all members of Grimaldi Moon Base staff, who manage instruments and observatories around the lunar surface. A swarm of meteoroids has hit the Moon, and the remote sensors report damage to some of the instruments. Your team must go out from Grimaldi Moon Base and retrieve the damaged instruments before the Sun sets. You've got more time than you think. On the Moon's surface it is light for 15 days and then dark for 15 days.

Some of the instruments are damaged more badly than others and will require 2 or more rovers to meet at the instrument to retrieve it. Only by working together – sharing resources and making joint plans – can you succeed in your mission to get back as many damaged instruments as possible before the long lunar night falls. As you make plans, remember that your number one goal is the safety of your team. Be sure to get everyone back before dark or you all lose.

Background Reading: The Moon

From the Family ASTRO Kit: *Moon Mission*

www.astrosociety.org/education/family/resources/moon.html

Our planet's satellite, which we call the Moon, is the easiest astronomical object to observe. The only "scientific instrument" you need is a pair of eyes. The Moon is the only thing in the sky (other than the Sun) that doesn't look like a point of light or an indistinct fuzzy patch to the unaided eye. Even more interesting is how the way the Moon looks to us continually changes. Keeping track of its appearance from night to night (or day to day) is a fascinating and easy way to get acquainted with the rhythms of change in the sky.

The Moon is small, only about a quarter the size in diameter of the Earth. Looking at its light and dark patches, many people are reminded of a face of a person or the shape of a rabbit. Early astronomers who studied the Moon with the first telescopes thought that the dark areas were vast oceans, and so they named them "mare," the Latin word for "sea." We now know there is no water on the Moon; in fact, it's a dry, airless world, not hospitable to any kind of life. The maria (the plural form of the word "mare") are really large, smooth plains formed out of solidified lava.

The lighter patches are rocky regions covered with *craters* – circular pits or basins blasted out by high-speed impacts from rocks and ice chunks of varying sizes (from objects the size of small cities down to boulders and pebbles). Most of the craters bear silent witness to a time, billions of years ago, when collisions between such debris and planets were much more common. The Earth also experienced a similar bombardment, but erosion by wind, water, and the movement of the Earth's crust has largely erased ancient craters from the Earth's surface. On the Moon there is no wind or rain to wash away the evidence, preserving the cosmic history of our "neighborhood" for humans to study.

We should note that, although impacts were more common in our system's early days, they still continue today. Chunks of rock and ice are still hitting both the Earth and the Moon.

The Moon has 80 times less material (mass) than the Earth and its surface gravity is about 1/6 of ours. This is why it had trouble holding on to light gases which might have given it an atmosphere.

Over the millennia, the Moon has become "locked" into a special kind of motion around the Earth. It rotates on its axis at the same pace as it revolves around the Earth. As a result, the Moon always keeps the same "face" pointed toward us throughout its orbit. This is why astronomers speak of the "nearside" (the side we see) and "farside" (the side we never see) of the Moon. Indeed, it wasn't until the 1960s, when we sent spaceships to fly around the Moon, that we got our first glimpse of the far side of the Moon.

We only see the Moon because sunlight reflects back to us from its surface; it has no light source of its own. During the course of a month, the Moon circles once around the Earth. Indeed, the word "month" comes from "Moon", and youngsters really enjoy it if you give them permission to say "moonth" instead of "month" for a while.

Half of the Moon is always lit by the Sun; but the lit-up side does NOT always face the Earth! As the Moon circles the Earth, the amount of its disk facing us that is lit by the Sun changes, altering how much of the lunar surface appears bright and how much is in darkness. The changes are known as phases, and repeat in a specific cycle each month. There are four primary phases: New Moon, First Quarter, Full Moon and Last Quarter. Each occurs about a week apart, with Last Quarter followed by another New Moon, which begins the cycle anew (it actually takes 29 and 1/2 days to go from one New Moon to the next).

Several points about the Moon's phases should be emphasized. First, during the week it takes to move from one phase to another, the amount of the Moon's surface lit by the Sun changes gradually; it's not an abrupt change from one phase to the next (which is the impression some textbooks give). Second, the Moon is not limited to the night sky. Near both First and Last Quarter you can see the Moon during the daytime. (See the table at the end of this section for more on when you can see the Moon.) Finally, it's worth repeating that the phases of the Moon arise because as the Moon circles the Earth, the amount of sunlight we see on its disk changes. The Earth's shadow plays no role in the Moon's phases.

But our shadow does darken the Moon during a lunar eclipse. Let's see why. The Earth circles the Sun once per year. The plane of the Earth's orbit is called the ecliptic. The Sun, the Earth and the Earth's shadow all fall within the plane of the *ecliptic*. The Moon circles the Earth once per month. The plane of the Moon's orbit is tilted a little bit (5°) from the plane of the ecliptic. When the Moon is on the side of the Earth furthest away from the Sun (Full Moon), it passes very close to the Earth's shadow; so there is a chance of an eclipse every month. Because its orbit is tilted, however, the Moon usually passes just above or below the Earth's shadow. About once every six months, the orbits cross and the Moon goes right through the shadow of the Earth, creating a lunar eclipse.

While in the Earth's shadow, the Moon looks reddish-orange. This deep color comes about because the Earth's atmosphere bends the red-orange part of sunlight into the shadow, just as it does at sunrise or sunset (the sky appears reddish when the Sun is below the horizon). How dark the Moon appears depends upon whether the Moon is crossing through the center of the Earth's shadow or nearer to the edge of the shadow, and how much dust or pollution is in the Earth's atmosphere.

In an amazing coincidence, the Sun and the Moon appear to us to be almost the same size in the sky. Although the Moon is actually hundreds of times smaller in size than the Sun, it is, completely by chance, just as many hundreds of times closer to the Earth. Because of this, if the Moon happens to pass directly between the Earth and Sun, it can momentarily block out the Sun, creating a solar eclipse. This happens when the Moon is on the same side of the Earth as the Sun (New Moon). Again, because of the tilt of the Moon's orbit, it usually passes just above or below the Sun's position at this time. But about every six months, the Moon passes directly between the Earth and the Sun. Because the Moon's shadow is so small, however, only a small portion of the Earth's surface will see the Moon completely block out the Sun, in a total solar eclipse. People outside of the small region of totality will see the Moon block only part of the Sun's surface – a partial solar eclipse; it looks like a "bite" has been taken out of the Sun.

The Moon is the only place in the entire solar system, other than Earth, on which humans have walked. The 12 astronauts who landed on the Moon in the late 1960s and early 1970s returned with boxes full of rocks taken from the Moon's

surface. Scientists continue to learn a great deal by studying these rocks. One of the things that close-up study of the Moon taught us is that its makeup is remarkably similar, yet subtly different from the Earth's. This led to a new theory of how the Moon originated. This "great impact" theory suggests that the early Earth was dealt a glancing blow by a giant chunk about the size of Mars. A great tongue of material splashed outward after the impact consisting of some of the Earth's mantle and some of the chunk that hit us. This splashed-out material went into orbit around the Earth and eventually condensed into the Moon.

Our increasing scientific understanding of the Moon need not take away from our response to its beauty. To be startled by the Full Moon rising in the eastern sky at sunset is to be confronted by one of Nature's greatest spectacles. Knowledge need not reduce our sense of awe; it can enhance it.

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Phase	Rises	Eastern Sky	Highest in Sky	Western Sky	Sets
New Moon	sunrise	morning	noon	afternoon	sunset
Waxing Crescent	just after sunrise	morning	just after noon	afternoon	just after sunset
First Quarter	noon	afternoon	sunset	evening	midnight
Waxing Gibbous	afternoon	sunset	night (pm)	midnight	night (am)
Full Moon	sunset	night (pm)	midnight	night (am)	sunrise
Waning Gibbous	night (pm)	midnight	night	sunrise	morning
Third Quarter	midnight	night (am)	sunrise	morning	noon
Waning Crescent	just before sunrise	morning	just before noon	afternoon	just before sunset

The Moon: A Resource Guide for Family ASTRO Leaders

BY ANDREW FRAKNOI *(Foothill College and ASP)*

Books about Our Scientific Understanding of the Moon

Chaikin, Andrew *A Man on the Moon.* 1994, Viking Press. A well-reviewed history of manned lunar exploration.

Harland, David *Exploring the Moon: The Apollo Expeditions.* 1999, Praxis/Springer-Verlag. Reviews the work of the astronauts on the Moon in the context of what we now know about lunar geology.

Hockey, Thomas *The Book of the Moon.* 1986, Prentice Hall. A basic primer on many aspects of the Moon.

Mackenzie, Dana *The Big Splat: How Our Moon Came to Be.* 2003, Wiley. A nice history of ideas about the Moon's origin, with a focus on the modern theory of a major collision.

Moore, Patrick *Patrick Moore on the Moon.* 2001, Cassell/Stirling. An updated edition of a classic book on the history of our understanding of the Moon, with observing hints and maps.

Spudis, Paul *The Once and Future Moon.* 1998, Smithsonian Inst. Press. A geologist discusses what our exploration of the Moon has taught us, and what we might do there in the future.

Books about Observing the Moon

Kitt, Michael *The Moon: An Observing Guide for Backyard Telescopes.* 1992, Kalmbach. Eighty-page illustrated primer for beginners.

North, Gerald *Observing the Moon: The Modern Astronomer's Guide.* 2000, Cambridge U. Press. Very detailed observing guide for serious Moon watchers.

Rukl, Antonin *Atlas of the Moon.* 1993, Kalmbach. Reference book which includes 76 carefully drawn maps of the Moon, plus an overview of what we know about our satellite and its motions.

Wlasuk, Peter *Observing the Moon.* 2000, Springer-Verlag. Guide to observing and the geology you can see.

Books about the Moon and Popular Culture (including Mythology)

Jablow, A. & Withers, C. *The Man in the Moon: Sky Tales from Many Lands.* 1969, Holt, Rinehart, and Winston.

Krupp, E.C. *Beyond the Blue Horizon: Myths and Legends of the Sun, Moon, Stars, and Planets.* 1991, HarperCollins. Superb collection of astronomical tales from many cultures. Best book to start with.

McVickar Edwards, Carolyn *In the Light of the Moon: Thirteen Lunar Tales from Around the World Illuminating Life's Mysteries.* 2003, Marlowe & Company.

Montgomery, Scott *The Moon and the Western Imagination.* 1999, U. of Arizona Press. A history of how we came to know the Moon, and the responses in literature, art, and philosophy.

A Few Children's Books about the Moon

Asimov, Isaac & Walz-Chojnacki, Greg *The Moon.* 1994, Gareth Stevens. Part of the Asimov library of astronomy for children.

Bredeson, Carmen *The Moon.* 1998, Franklin Watt/Grolier. For younger kids.

Cole, Michael *The Moon: Earth's Companion in Space.* 2001, Enslow.

Davis, Don & Hughes, David *The Moon.* 1989, Facts on File. Part of the Planetary Exploration series for middle-school students.

Hitt, Robert *The Moon.* 1998, Grolier/Michael Friedman. 64-page introduction to Moon motions and exploration.

Krupp, E. C. *The Moon and You.* 1993, Macmillan. Beautifully illustrated primer for younger children by a noted astronomy educator.

Rosen, Sidney *Where Does the Moon Go?* 1992, Carolrhoda Books. Primer for younger kids by an astronomer.

Stott, Carol *Moon Landing: The Race for the Moon.* 1999, DK Books. Lavishly illustrated.

Vogt, Gregory *Apollo Moonwalks: The Amazing Lunar Missions.* 2000, Enslow. Nice review by a NASA educator.

Articles about Our Scientific Understanding of the Moon

Comins, N. "What If: The Earth Without a Moon" in *Astronomy,* Feb. 1991, p. 49. Good scientific speculation of how the absence of the Moon would have affected the Earth.

Foust, J. "NASA's New Moon" in *Sky & Telescope,* Sep. 1998, p. 48. On results from the Lunar Prospector mission.

Hurt, H. "I'm at the Foot of the Ladder" in *Astronomy,* July 1989, p. 22. A review of the Apollo missions to the Moon.

Jayawardhana, R. "Deconstructing the Moon" in *Astronomy,* Sep. 1998, p. 40. An update on the giant impact hypothesis for forming the Moon.

Ryder, G. "Apollo's Gift: The Moon" in *Astronomy,* July 1994, p. 40. Good evolutionary history of the Moon.

Schmitt, H. "Exploring Taurus–Littrow: Apollo 17" in *National Geographic,* Sep. 1973. First-person account by the only scientist to walk on the Moon.

Sinnott, R. "Seeking Thin Crescent Moons" in *Sky & Telescope*, Feb. 2004, p. 102. On finding the Moon as early in its monthly cycle as possible (hints and record holders.)

Spudis, P. "How the Earth Got Its Moon" in *Astronomy,* July 2004, p. 42. On the origin of our satellite.

Spudis, P. "The Giant Holes of the Moon" in *Astronomy,* May 1996, p. 50. On the results of the Clementine mission.

Articles about Observing the Moon for Yourself

Burnham, R. & Therin, G. "The Joys of Moongazing" in *Astronomy,* Mar. 1991, p. 84. Observing and photography with modest telescopes.

Chaikin, A. "A Guided Tour of the Moon" in *Sky & Telescope,* Sep. 1984, p. 211. An observing guide for beginners.

Coco, M. "Staging a Moon Shot" in *Astronomy,* Aug. 1992, p. 62. How to photograph the Moon.

MacRobert, A. "Close-up of an Alien World" in *Sky & Telescope,* July 1984, p. 29. An observing guide.

McConnell, D. "Basic Lunar Astrophotography" in *Astronomy,* Dec. 1985, p. 69.

Shibley, J. "Simple Telescopic Shooting" in *Astronomy*, Oct. 2003, p. 86. A beginner's guide to photographing the Moon.

Sky & Telescope magazine offers a column called "Lunar Notebook" for serious Moon gazers.

Articles about the Future Exploration of the Moon

Burns, J., et al. "Observatories on the Moon" in *Scientific American,* March 1990, p. 42.

Lowman, P. "Regards from the Moon" in *Sky & Telescope,* Sep. 1992, p. 259. Good article in the form of a letter from a base on the Moon.

Nichols, R. "From Footprints to Foothold" in *Astronomy,* July 1989, p. 48. On possible future missions.

Spudis, P. "Harvest the Moon" in *Astronomy*, June 2003, p. 42. Some justifications for returning to the Moon.

Articles about the Moon in Popular Culture (including Mythology)

Ahmad, I. & Khalid Shaukat, S. "Muslim Moon Sightings" in *Mercury* (the magazine of the Astronomical Society of the Pacific), May/June 1995, p. 38. The Muslim calendar and sighting the first crescent Moon.

Olson, D. & Doescher, R. "D-Day: June 6, 1944" in *Sky & Telescope,* June 1994, p. 84. On the tides at Omaha beach.

Rotton, J. & Kelly, I. "The Lunacy of It All: Lunar Phases and Human Behavior" in *Mercury,* May/June 1986, p. 1988.

Rubincam, D. & Rowlands, D. "The Night the Titanic Went Down" in *Sky & Telescope,* Oct. 1993, p. 79.

Schaefer, B. "Lunar Eclipses That Changed the World" in *Sky & Telescope,* Dec. 1992, p. 639.

Sheehan, W. "The Moon Illusion" in *Mercury,* Jan/Feb. 2001, p. 12.

Vialle, J. & Hoff, D. "The Astronomy of Paul Revere's Ride" in *Astronomy,* Apr. 1992, p. 13.

General Moon Web Sites

The Nine Planets Site (Amateur astronomer Bill Arnett has compiled good introductory information and links for armchair explorers): http://nineplanets.org/luna.html

Views of the Solar System Site (Engineer Calvin Hamilton has a treasure trove of images, animations, information, and links): http://www.solarviews.com/eng/moon.htm

Planetary Sciences Site (from NASA's National Space Science Data Center, includes lots of information, mission guides, a timeline, images, and links): http://nssdc.gsfc.nasa.gov/planetary/planets/moonpage.html

Exploring the Moon (from the Lunar and Planetary Institute, focuses on the science and past and future missions; rich with maps and images) http://cass.jsc.nasa.gov/pub/expmoon/lunar_missions.html

Web Sites about Observing the Moon

Sky & Telescope Magazine Moon Site (includes articles, observing hints, and a discussion of what "blue moon" means; some of the articles recommended above are on-line here): http://skyandtelescope.com/observing/objects/moon/

Inconstant Moon (Kevin Clarke's rich site full of Moon information, observing guides, an atlas, phase calendar, Moon music, and much more): http://www.inconstantmoon.com

Hitchhiker's Guide to the Moon (Akanna Peck's site shows what's visible on the Moon tonight and let's you search by feature names; for serious observers): http://www.shallowsky.com/moon/hitchhiker.html

The Digital Lunar Orbiter Photographic Atlas of the Moon (photographs of the Moon from orbit, which can be explored in a variety of ways on line): http://www.lpi.usra.edu/research/lunar_orbiter/index.html

Web Sites for Keeping Track of the Moon's Phases

Googol Moon Phase Calendar (lets you print out a month-long pictorial calendar of what the Moon looks like for any month – past, present or future): http://www.googol.com/moon/moonctrl.pl.cgi

U.S. Naval Observatory Phase Calculator (another applet for showing the phase of the Moon on any selected date): http://tycho.usno.navy.mil/vphase.html

Earth and Moon Viewer (has a sophisticated program for seeing what the Moon looks like from several vantage points): http://www.fourmilab.ch/earthview/vplanet.html

Web Sites for Teachers

Astronomy Activities on the Web (a subject guide from the Astronomical Society of the Pacific, includes a number of good activities related to the Moon): http://www.astrosociety.org/education/activities/astroacts.html

SpaceLink Guide to Moon Resources for Teachers (a compilation of what materials NASA has on the Web for teachers relating to the Moon): http://spacelink.nasa.gov/Instructional.Materials/Curriculum.Support/Space.Science/Our.Solar.System/

Phases of the Moon Video Demo (Project ASTRO Tucson has an on-line demonstration of how Moon phases work): http://www.noao.edu/education/phases/phases_demo.html

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