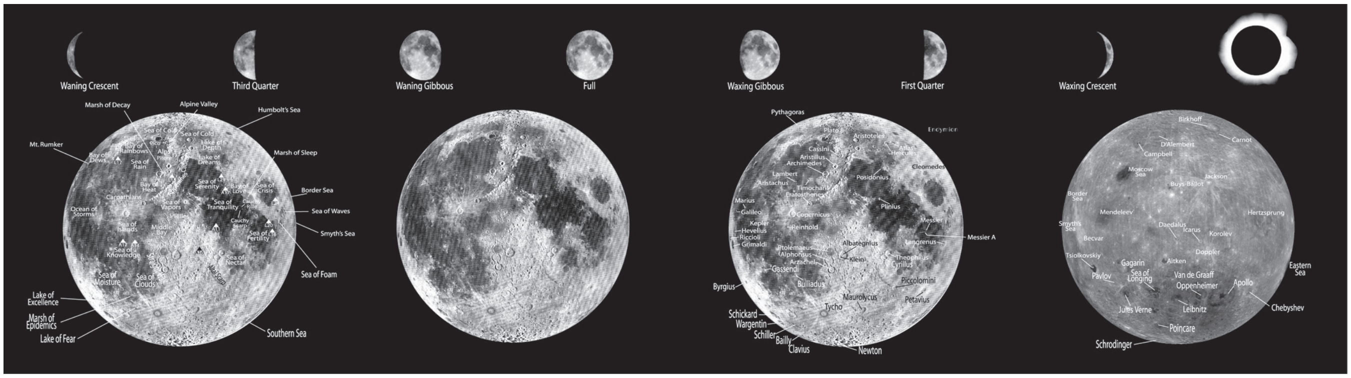
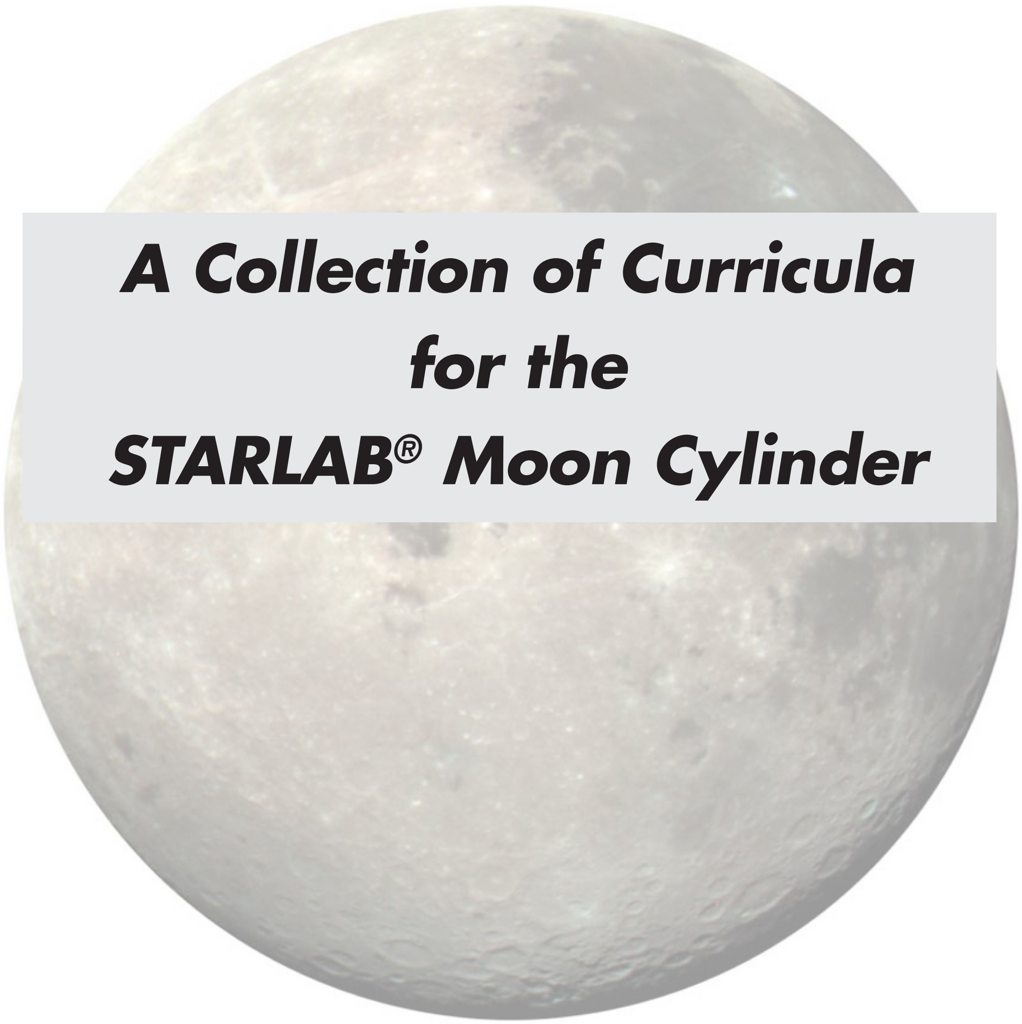




A Collection of Curricula for the STARLAB® Moon Cylinder

Including:

The Moon Cylinder Curriculum Guide by John T. Meader

STARLAB

Curriculum Guide Contents

Introduction

The most prominent feature in the night sky, to even the youngest children, is the Moon. The Moon is the only night-sky object beyond the clouds that appears larger than a dot. Yet, it is greatly misunderstood. Why it changes its phase, how it moves through the heavens, what the surface features really are — these are all aspects of the Moon that can be readily observed but that are plagued with misconceptions.

The Moon Cylinder, in conjunction with this curriculum guide, will help you teach your students about phases, eclipses, the Moon's motion through the heavens, and features on the Moon's surface. You will be able to examine and compare sites of the Apollo Moon landings, compare the near and far sides of the lunar surface, and distinguish between such surface features as highlands, maria, craters, mountains, ejecta rays, and rilles.

The cylinder comes with a masking cover, which can be used to obscure parts of the cylinder from view, thus keeping your students on task. With the phase identification activity, the mask is designed to allow viewing of only one phase at a time. This allows you to unveil the correct phase once your students' phase predictions have been cast.

The Major Features Found on the Moon Cylinder

- On the top of the cylinder is a diagram of the Earth as seen from below the south pole, Sun, and Moon's orbit. The position of the Moon at each major phase point is marked. The Moon's phase positions are not illustrated with pictures of each phase, instead it shows the Moon as half lit, half dark.

  Note

  It is important to remember that the Moon moves to the left or eastward as it crosses the sky, therefore the diagram progresses clockwise.

- At the top of the cylinder walls are a series of small pictures of the Moon during each phase. These pictures align with the top diagram. Remember that the proper progression of phases moves to the left. There is no picture of the New Moon as this cannot be seen. Instead, there is a picture of a total solar eclipse. Total solar eclipses only occur at the new moon phase when the alignment is very exact (which usually only happens twice per year).
- Centered around the main cylinder walls, just below the phase pictures mentioned above, are four large images of the Moon. There are three pictures of the near side of the Moon and one picture of the far side of the Moon. The three pictures of the near side of the Moon consist of one without labels; one with labels of the seas (or maria), and mountains; and one that depicts significant craters. The fourth picture is of the far side of the Moon with only major features labeled.

Labeled Features on the Large Pictures of the Moon

We use the English translations on the cylinder rather than the traditional Latin.

Near Side Maps (presented in approximate order of size)

Seas	***Maria***	***Notes***
Ocean of Storms	*Oceanus Procellarum*	*The largest mare, Apollo 12*
Sea of Rain	*Mare Imbrium*	*The youngest mare on the near-side*
Sea of Serenity	*Mare Serenitatis*	
Sea of Fertility	*Mare Fecunditatis*	
Sea of Tranquility	*Mare Tranquillitatis*	*Apollo 11*
Sea of Crisis	*Mare Crisium*	
Sea of Moisture	*Mare Humorum*	
Sea of Nectar	*Mare Nectaris*	
Sea of Cold	*Mare Frigoris*	
Southern Sea	*Mare Australe*	*Barely visible along southeastern limb*
Sea of Knowledge	*Mare Cognitum*	
Sea of Islands	*Mare Insularium*	*Often regarded as part of Ocean of Storms, Apollo 12*
Sea of Clouds	*Mare Nubium*	
Border Sea	*Mare Marginis*	
Smyth's Sea	*Mare Smythii*	
Foaming Sea	*Mare Spumans*	
Sea of Waves	*Mare Undarum*	
Humboldt's Sea	*Mare Humboldtianum*	*Visible along northeastern limb*
Sea of Vapors	*Mare Vaporum*	

Bays	***Sinus***
Central Bay	*Sinus Medii*
Bay of Heats	*Sinus Aestuum*
Bay of Dew	*Sinus Roris*
Bay of Love	*Sinus Amoris*
Bay of Rainbows	*Sinus Iridum*

Lakes	***Lacus***
Lake of Death	*Lacus Mortis*
Lake of Dreams	*Lacus Somniorum*
Lake of Excellence	*Lacus Excellentiae*
Lake of Fear	*Lacus Timoris*

Marshes	***Palus***
Marsh of Decay	*Palus Putredinis*
Marsh of Sleep	*Palus Somnii*
Marsh of Epidemics	*Palus Epidemiarum*

Mountain Ranges	***Montes***	***Notes***
Alps	*Montes Alpes*	*Famous for the Alpine Valley, length: 180 km/112 mi.*
Apennines	*Montes Apenninus*	*Tallest mountain range on the Moon, heights to over 5,000 meters/16,000 ft.*
Carpathians	*Montes Carpatus*	
Caucasus	*Montes Caucasus*	

Mountains	***Mons***	***Notes***
Mt. Huygens	*Mons Huygens*	*One of the tallest mountains, 5,400 m./17,700 ft., located in the Apennine Mountains*
Mt. Pico	*Mons Pico*	*Monadnock, solitary mountain, 2,400 m. /7,900 ft.*
Mt. Piton	*Mons Piton*	*Monadnock, solitary mountain, 2,200 m. /7,200 ft.*
Mt. Rumker	*Mons Rumker*	*Complex of volcanic domes*

Scarps or Cliffs	***Rupes***	***Notes***
Altai Scarp	*Rupes Altai*	*A long series of scarps or cliffs, 480 km. /298 mi. long and 1,000m/3,000 ft. high*
Cauchy Scarp	*Rupes Cauchy*	*A long fault line cliff, 120 km./75 mi. long, just south of Rima Cauchy*
Straight Wall	*Rupes Recta*	*A very straight fault line cliff, 110 km. /68 mi. long and 300 m./1,000 ft. high*

Rilles (grooves)	***Rimae***	***Notes***

(Identified on the cylinder as simply rilles without names, these are the rilles that will be labeled as such. Rilles are thought to be emply lava riverbeds or sunken faults.)

Ariadaeus	*Rima Ariadaeus*	*Ariadaeus (220 km./136 mi. long) & Triesnecker*
Triesnecker	*Rimae Triesnecker*	*(200 km./124mi. long) are part of an extensive region of rilles south of the Sea of Vapors.*
Cauchy Rille	*Rima Cauchy*	*Compare this rille (210 km./130 mi. long) to the nearby Cauchy Rupe (scarp), in the Sea of Tranquility*

Landing Sites/ Abbrev	***Date***	***Location***	***Astronauts (landed, landed, orbited)***
Apollo 11/Ap11	*7/20/1969*	*Sea of Tranquility*	*Armstrong, Aldrin, Collins*
Apollo 12/Ap12	*11/19/1969*	*Ocean of Storms/Sea of Islands*	*Conrad, Bean, Gordon*
Luna 16/L16	*9/21/1970*	*Sea of Fertility*	*1st Soviet sample return mission*
Luna 17/L17	*11/17/1970*	*Sea of Rain*	*Soviet rover Lunokhod 1*
Apollo 14/Ap14	*2/5/1971*	*Near Frau Mauro Crater*	*Shepard, Mitchell, Roosa*
Apollo 15/Ap15	*7/30/1971*	*Hadley Rille, Apennine Mtns.*	*Scott, Irwin, Worden*
Luna 20/L20	*2/21/1972*	*Eastern Highlands*	*2nd Soviet sample return mission*
Apollo 16/Ap16	*4/21/1972*	*Descartes Crater, Central Highlands*	*Young, Duke, Mattingly*
Apollo 17/Ap17	*12/11/1972*	*Littrow Crater, Eastern Highlands*	*Cernan, Schmitt, Evans*

Landing Sites/ Abbrev	Date	Location	Astronauts (landed, landed, orbited)
Luna 21/L21	1/15/1973	le Monnier, Sea of Serenity	Soviet rover Lunokhod 2
Luna 24/L24	8/18/1976	Sea of Crisis	3rd Soviet sample return mission

Craters	Diameter km/mi	Namesake/Description
(Craters discussed in the lesson are marked by an *asterisk. Craters are listed generally north to south.)		
Pythagoras	142 km/88 mi	Greek philosopher/mathematician, ca. 532 B.C.
Endymion	123 km/76 mi	Greek mythical character spellbound by Selene, Goddess of the Moon
Aristoteles	87 km/54 mi	Greek astronomer/philosopher, 384–322 B.C.
*Plato	109 km/68 mi	Greek philosopher, ca. 428–ca. 347 B.C., very dark crater due to lava
Hercules	69 km/43 mi	Greek mythical hero
Atlas	87 km/54 mi	Mythical Greek Titan
*Cassini	56 km/35 mi	French astronomer, 1677–1756
Aristillus	55 km/34 mi	Greek astronomer, ca. 280 B.C.
Posidonius	95 km/59 mi	Greek geographer, ca. 135–ca. 51 B.C.
Archemedes	82 km/51 mi	Greek physicist/mathematician, ca. 287–212 B.C.
Aristachus	40 km/25 mi	Greek astronomer, 310–230 B.C.
Lambert	30 km/19 mi	German astronomer/mathematician, 1728–1777
Timocharis	33 km/20 mi	Greek astronomer, ca. 280 B.C.
Cleomedes	125 km/78 mi	Greek astronomer, unknown–ca. 50 B.C.
Erotosthenes	58 km/36 mi	Greek astronomer/geographer, ca. 276–194 B.C.
Plinius	43 km/27 mi	Roman natural scientist, 23–ca. 79 A.D.
*Marius	41 km/25 mi	German astronomer, 1570–1624
*Copernicus	107 km/66 mi	Polish astronomer, 1473–1543
*Kepler	31 km/19 mi	German astronomer, 1571–1630
Reinhold	42 km/26 mi	German astronomer/mathematician, 1511–1553
*Galileo	15 km/9 mi	Italian astronomer, 1564–1642
Hevelius	115 km/71 mi	Polish astronomer/selenographer, 1611–1687
*Riccioli	139 km/86 mi	Italian astronomer/selenographer, 1598—1671
*Grimaldi	172 km/107 mi	Italian astronomer/selenographer, 1618–1663, darkest crater on near side
*Ptolemaeus	164 km/102 mi	Greek astronomer/mathematician/geographer, ca. 87–150 A.D.
*Alphonsus	108 km/67 mi	Spanish astronomer, 1223–1284
*Arzachel	96 km/60 mi	Spanish-Arabic astronomer, ca. 1028–1087
*Albategnius	114 km/71 mi	Iraqi astronomer, 850–929 A.D.
*Klein	44km/27 mi	German astronomer, 1844–1914, crater is found inside the crater Albategnius
Theophilius	110 km/68 mi	Greek astronomer, unknown–412 A.D.
Cyrillus	98 km/61 mi	Egyptian theologian/chronologist, unknown–444 A.D.
*Messier & Messier A	11 km/7 mi	French astronomer, 1730–1817, dual craters with westerly pointing rays
Gassendi	101 km/63 mi	French astronomer/mathematician, 1592–1655
Bulliadus	60 km/37 mi	French astronomer, 1605–1694

Craters	*Diameter km/mi*	*Namesake/Description*
Piccolomini	*87 km/54 mi*	*Italian astronomer, 1508–1578*
Langrenus	*127 km/79 mi*	*Belgian selenographer/engineer, ca. 1600–1675*
**Tycho*	*102 km/63 mi*	*Danish astronomer, 1546–1601, most extensive ray system*
Maurolycus	*114 km/71 mi*	*Italian mathematician, 1494–1575*
Clavius	*245 km/152 mi*	*German mathematician, 1537–1612*
Byrgius	*87 km/54 mi*	*Swiss horologist, 1552–1632*
Petavius	*188 km/117 mi*	*French chronologist/astronomer, 1583–1652*
Schickard	*206 km/128 mi*	*German astronomer/mathematician, 1592–1635*
Wargentin	*84 km/52 mi*	*Swedish astronomer, 1717–1783, crater is filled to the brim with lava*
Schiller	*180 km/112 mi*	*German astronomer, ca. 1627*
Bailly	*287 km/178 mi*	*French astronomer, 1736–1793, largest crater on near side*
Newton	*78 km/48 mi*	*British mathematician/physicist/astronomer, 1642–1727, deepest crater*

Far Side Map

Seas	*Maria*	*Notes*
Presented in approximate order of size.		
Eastern Sea	*Mare Orientale*	*The youngest mare*
Southern Sea	*Mare Australe*	*Partly visible along limb of the near side*
Border Sea	*Mare Marginis*	*Partly visible along limb of the near side*
Smyth's Sea	*Mare Smythii*	*Partly visible along limb of the near side*
Moscow Sea	*Mare Moscoviense*	
Sea of Longing	*Mare Ingenii*	

Craters	*Diameter km/mi*	*Namesake/Description*
Birkhoff	*345 km/214 mi*	*American mathematician, 1884–1944*
Carnot	*126 km/78 mi*	*French physicist, 1796–1832*
Campbell	*219 km/136 mi*	*Two american astronomers, 1862–1938; 1881–1951*
D'Alembert	*248 km/154 mi*	*French mathematician, 1717–1783*
Buys-Ballot	*55 km/34 mi*	*Dutch meteorologist, 1817–1890*
Jackson	*71 km/44 mi*	*Scottish astronomer, 1887–1958*
Mendeleev	*313/194 mi*	*Russian chemist, 1834–1907*
Hertzsprung	*591 km/367 mi*	*Danish astronomer, 1873–1967*
Becvar	*67 km/42 mi*	*Czechoslovakian astronomer, 1901–1965*
Daedalus	*93 km/58 mi*	*Greek mythological character who flew with wings of feathers and wax*
Icarus	*96 km/60 mi*	*Greek mythological character who flew with wings of feathers and wax*
Korolev	*437 km/271 mi*	*Soviet rocket scientist, 1906–1966*
Doppler	*110 km/68 mi*	*Austrian physicist/mathematician, astronomer, 1803–1853*
Tsiolkovskiy	*185 km/115 mi*	*Soviet physicist, 1857–1935*
Gagarin	*265 km/165 mi*	*Soviet cosmonaut, 1934–1968 First man in space*
Aitken	*135 km/84 mi*	*American astronomer, 1864–1951*
Pavlov	*148 km/92 mi*	*Soviet physiologist, 1849–1936*

Craters	***Diameter km/mi***	***Namesake/Description***
Jules Verne	*143 km/89 mi*	*French science fiction writer, 1828–1905*
Van de Graaff	*233 km/145 mi*	*American physicist, 1901–1967*
Oppenheimer	*208 km/129 mi*	*American physicist, 1904–1967*
Apollo	*537 km/334 mi*	*Named to honor Apollo Moon missions*
Chebyshev	*178 km/111 mi*	*Russian mathematician, 1821–1894*
Leibnitz	*245 km/152 mi*	*German mathematician/physicist/philosopher, 1646–1716*
Poincare	*319 km/198 mi*	*French mathematician/physicist, 1854–1912*
Schrodinger	*312 km/194 mi*	*Austrian physicist, 1887–1961*

Classroom Activities

These questions, vocabulary words, puzzles, and activities are designed to help prepare your students for concepts discussed within the dome.

20 Questions

1. Why does the Moon change phases?
2. How long does it take the Moon to go through one complete set of phases (full Moon to full Moon)?
3. What unit of time is directly related to one orbit of the Moon around the Earth?
4. What keeps the Moon in orbit around the Earth?
5. How are craters formed?
6. Can the Space Shuttle go to the Moon?
7. How much gravity does the Moon have?
8. Why does the Moon have more craters than the Earth?
9. How many astronauts have walked on the Moon?
10. Who was the first person to step on the Moon?
11. What were his words as he first stepped on the Moon?
12. Who was the second man on the Moon?
13. Is the far side of the Moon always dark?
14. Why are the dark areas on the Moon called maria, which means seas?
15. Where was water ice found on the Moon's surface?
16. Why is finding water on the Moon important?
17. Which rocket was used to send astronauts to the Moon?
18. List the Moon's major phases in order from new Moon to new Moon.
19. What is the terminator line?
20. Why are the astronaut's footprints still on the Moon today, even though they were made between 1969 and 1972?

Answers to 20 Questions

1. The Moon changes shape because of two things. First, the Sun only lights up half the Moon at a time–the half that faces the Sun. Second, the Moon revolves around the Earth, which makes us see different parts of the sunlit areas of the Moon's surface.
2. One orbit, full moon to full moon, is 29.5 days.
3. The "month" is derived from the length of time it takes the Moon to orbit Earth once. A month comes from a "Moonth".
4. Gravity keeps the Moon from flying away from Earth; centrifugal force created by the Moon's motion keeps gravity from pulling the Moon into the Earth. The two forces are balanced.
5. Craters are caused by meteoroids, which are rocks that hit planets and moons. They can be very large (miles in diameter) or very small (specks of dust).
6. No, the Space Shuttle cannot go to the moon. It does not have enough power to fly that far away.
7. The Moon has 1/6th the gravity of Earth. To find out what you would weigh on the Moon, simply divide your weight by six.
8. The Moon has no air or weather. On Earth, meteors burn due to friction with the atmosphere. Most never reach the ground. If they do hit the ground and create a crater, the weather eventually erodes the crater away. On the Moon, with no air or weather, they all hit the surface. The only thing to destroy old craters is the impact of a new one on top of the old one.
9. Twelve astronauts have walked on the Moon's surface.
10. Neil Armstrong was the first to step on the Moon.
11. "One small step for man, one giant leap for mankind."
12. Buzz Aldrin was the second man on the Moon.
13. No. The far side of the Moon receives just as much light as the near side.
14. The dark areas on the Moon, the **maria,** were called that because long ago people thought those areas might actually be seas of water. Even though we now know there is no water in the maria, we still use the term.
15. Evidence of water was recently discovered frozen deep in craters at both the north and south poles of the Moon. There may be as much as six-billion metric tons of water ice in these two regions. The ice was discovered by the **Clementine** and **Lunar Prospector** probes.
16. Finding water on the Moon is important for future Moon outposts. This would mean that water would not have to be brought there from Earth, which is very expensive. Water is needed not only for people, plants, and animals to live, but it can also be used for rocket fuel.
17. The Saturn V rocket was used to send all the Apollo astronauts to the Moon.
18. The Moon's phases: New Moon, Waxing Crescent, First Quarter, Waxing Gibbous, Full Moon, Waning Gibbous, Third Quarter, Waning Crescent, New Moon.
19. The terminator is the line between daylight and darkness on the Moon (or any other planet for that matter!).

20. The astronaut's footprints will remain on the Moon for thousands of years because there is no air or weather to erode them. The only things that might destroy the footprints would be if a meteorite should hit the footprint, or if we go back to the Moon and mess them up!

The Face of the Moon

Use this map to help familiarize younger students with the Moon's landscape.

Maria or Seas

Mare Australe/The Southern Sea
Mare Crisium/The Sea of Crises
Mare Fecunditatis/The Sea of Fertility
Mare Frigoris/The Sea of Cold
Mare Humorum/The Sea of Moisture
Mare Imbrium/The Sea of Showers
Mare Marginis/The Sea of Margins
Mare Nectaris/The Sea of Nectar
Mare Nubium/The Sea of Clouds
Oceanus Procellarum/The Ocean of Storms
Mare Serenitatis/The Sea of Serenity
Mare Tranquillitatis/The Sea of Tranquility
Mare Vaporum/The Sea of Vapours

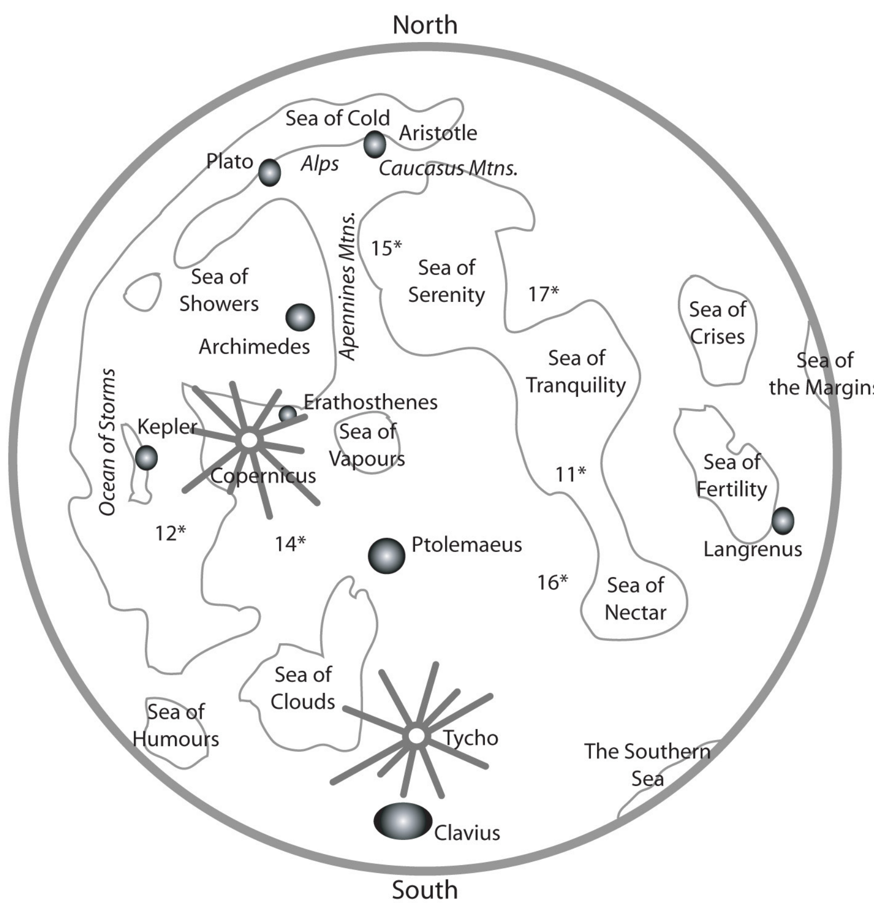
Craters

Archimede
Aristotle
Clavius
Copernicus
Eratosthenes
Kepler
Langrenus
Plato
Ptolemaeus

Mountain Ranges

Alps
Apennines
Caucasus

** Apollo Landing Sites*



Vocabulary

Apollo Mission

The name given to the series of spacecraft that made voyages to the Moon in the late 1960s and early 1970s.

Clementine Probe

A space probe that was launched on January 25, 1994. It completed the first digital mapping of the Moon's surface.

Earthshine

When the Moon is in its crescent phase, the dark nighttime area can be seen if you look carefully. It is being illuminated by sunlight that is reflecting off Earth and bouncing up, faintly lighting the Moon.

Eclipse

An eclipse happens when the Moon moves directly in front of the Sun. For this to happen the Sun, Moon, and Earth must be exactly aligned. If the Moon is in the middle, it blocks the Sun's light and creates a **Solar Eclipse**. If the Earth is in the middle, Earth blocks the Sun's light from hitting the Moon and creates a **Lunar Eclipse**.

Highlands

The white appearing areas on the Moon's surface. They are made up of hills, mountains, valleys, craters, and generally rugged terrain. The rocks in the highlands are much older than the rocks in the maria.

Lunar Prospector

A space probe that was launched on January 6, 1998. It orbited the Moon at an altitude of 97 kilometers/60 miles and was designed to study the geology of the Moon. It confirmed the existence of water deep in craters near the Moon's poles.

Maria

The plural term for **mare**. The maria are what appear as darker areas on the Moon's surface. They are not craters, but ancient lava flows. The term "mare" actually means sea because hundreds of years ago many people perceived them as lunar oceans.

Phases

The various appearances of the lit side of the Moon as seen at different points along its orbit. The Moon completes a set of phases with each orbit around the Earth. The phases of the Moon listed in order are: New Moon, Waxing Crescent, First Quarter, Waxing Gibbous, Full Moon, Waning Gibbous, Third Quarter, Waning Crescent, New Moon.

Saturn V Rocket

The large rocket built to launch the Apollo spacecraft to the Moon. It stood 111 meters/365 feet tall, nearly 61 meters/200 feet taller than the Space Shuttle!

Selenography

The scientific mapping of the Moon.

Selenology

The study of the Moon.

Terminator

The line between day and night on the Moon. On the terminator line, you would be watching the Sun either set or rise. This is where shadows are longest, which highlights the contours of the Moon's surface. This is the most interesting place to look at the Moon with a telescope or binoculars.

Moon Distance Puzzle

Did you ever notice that the Moon and Sun appear to be exactly the same size in the sky? Yet, we all know that the Sun is larger than the Moon. Actually the Sun's diameter is 400 times greater than the Moon's diameter. The Moon appears to be the same size because of a rare coincidence: The Moon is exactly 400 times closer to us than the Sun. That makes the two objects appear to be the same size in the sky.

Many people have a difficult time understanding how close the Moon is to us compared to the Sun, so here's a puzzle for you to contemplate. The information that you need to solve this puzzle is found in the above paragraph.

Imagine a scale model of the distance between the Earth, Sun and Moon using a 40-story building. The Earth is the ground floor and the Sun is on the top floor. There are 10 steps between each floor. On which step, between which floors, would you place the Moon to have the correct scale model of distance.

Hint

Figure out how many steps there are by multiplying the number of steps between each floor by the number of floors.

Fill in the Blanks

The Moon would be on step number ____________, above floor number _____________.

Answer

The Moon would be on step number 1, above floor number 1. There are ten steps between each floor and forty floors in all. 40 floors X 10 steps = 400 steps total. Since the Sun is 400 times farther away than the Moon, the Moon must therefore belong on the very first step!

The First Footstep on the Moon

The astronauts left many footprints on the surface of the Moon. This picture is of the first step taken on the Moon's surface. Notice how sharp and clean the edges are. It looks like Neil Armstrong just made that print (actually, he had when the picture was taken!). If we were to go back there today, the footprint would look exactly the same.

- Why would Neil Armstrong's footprint look just the same after so many years?
- What might naturally change or destroy the footprint's appearance on the Moon?
- Can footprints on Earth last for more than thirty years? Why?
- Set up an experiment where your students make good sharp edged footprints in different areas (ie. In a high foot-traffic area, in a low foot-traffic area, in the open, under trees, in dirt, in snow, in slush, etc.). Monitor how the prints deteriorate over time (hours, days). How does the environment affect the longevity of the print?
- How long do footprints usually last on Earth?
- Name three reasons that tracks on Earth disappear.

Blackpoll Warbler. Courtesy of the U.S. Fish & Wildlife Service

Lunar Word Prospecting

Find the lunar words hidden in the puzzle below. The words may be found horizontally, vertically, or diagonally.

Moonbase	*Mare*	*Highlands*	*Luna*
Lunar Module	*Apollo*	*Eclipse*	*Month*
Phases	*Crescent*	*Rover*	*Ejecta*
Satellite	*Neil Armstrong*	*Sea*	*Crater*
Earth	*NASA*	*Spacesuit*	*Gravity*
Moonrock	*Orbit*	*First Quarter*	*Astronaut*
Full Moon	*Saturn V Rocket*		

M	S	E	N	O	R	U	T	M	V	E	M	O	O	N	R	O	C	K	N
T	A	P	J	B	A	L	K	M	O	O	N	B	A	S	E	E	Z	F	D
O	T	S	A	E	N	L	S	A	Q	N	L	T	P	A	C	O	E	U	M
B	U	H	T	X	C	A	G	R	E	U	T	S	O	B	D	I	S	L	E
G	R	B	I	U	B	T	S	E	A	M	D	H	L	G	H	G	E	L	E
R	N	E	S	G	R	N	A	A	K	J	P	O	L	U	S	C	E	M	F
A	V	U	P	L	H	P	Z	L	U	N	A	R	O	V	E	R	H	O	S
V	R	G	A	T	E	L	U	N	A	R	M	O	D	U	L	E	C	O	A
I	O	R	C	D	C	R	A	T	E	R	A	O	Y	E	N	S	N	N	T
T	C	I	E	J	L	F	X	N	L	A	H	K	R	C	R	C	E	I	E
Y	K	J	S	D	I	D	A	S	D	E	R	H	G	B	N	E	E	M	L
X	E	V	U	C	P	H	A	S	E	S	B	T	Y	A	I	N	R	H	L
E	T	H	I	A	S	T	R	O	N	A	U	T	H	J	C	T	G	P	I
X	O	M	T	N	E	I	L	A	R	M	S	T	R	O	N	G	I	K	T
G	F	I	R	S	T	Q	U	A	R	T	E	R	R	S	K	E	P	V	E

Materials

- STARLAB Portable Planetarium
- Starfield Cylinder and magnetic Moon Phases
- Small Post-it® note pad (the smaller the better)

STARLAB Lesson 1: The Moon´s Motion Through the Sky

Objectives

- To discover how the Moon travels through the night sky and predict its movements.
- To discover how the phases change as the Moon orbits Earth.

Lesson Length

30 minutes. *(STARLAB lessons 1 & 2 can be easily combined into a complete and complimentary one hour session.)*

Suggested Grade Levels

This lesson can be modified from a simplified version for as young as third grade to a more fully developed lesson for middle school students.

Integrated Subjects

- Science
- Astronomy
- Geometry
- Physics
- Time

Processing Skills

Listening • Observing • Interpreting • Discovering • Reasoning • Predicting • Making Hypothesis and Conclusions

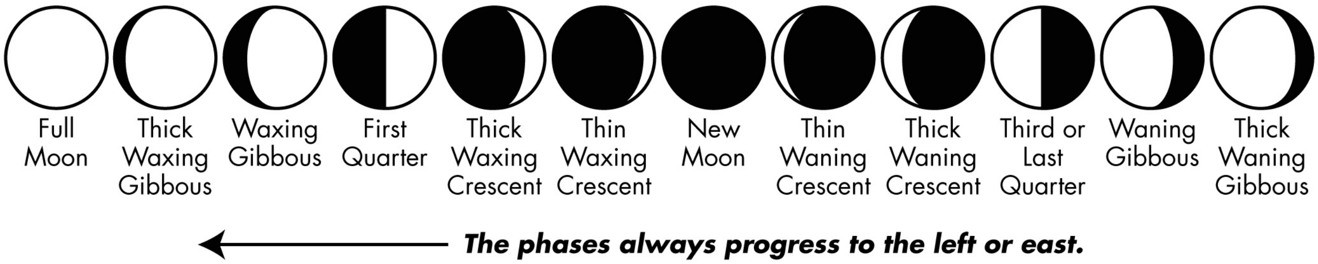
Preparation

> **Important Note!**
>
> ***Warning — confusing concept ahead! The Moon moves east and west at the same time!*** *Beware of the Moon's confusing motions. There are two different motions involved with our perception of how the Moon moves through the sky. Hourly observations will tell you that the Moon moves westward through the course of the night; however, if you carefully plot the Moon's position in the stars each hour, you will find that it is moving eastward through the stars. The Moon always moves left or eastward through the stars as it travels through its orbit. The Moon's true eastward motion is often hidden by the fact that we are on Earth which rotates eastward faster than the Moon moves eastward. This makes the Moon and the stars drift together westward through the course of the night. The best way to see the Moon's true eastward motion is to plot the Moon's position in the sky at the same time each night. You will find that each successive night the Moon will be found further eastward than it was the previous night at the same time.*

- Read the supporting material provided in this lesson plan and curriculum guide.
- Attach the magnetic Moon phases to the Starfeld Cylinder in the correct order as illustrated here (*south at bottom*).

Note

Remember that the Moon moves eastward or left across the sky, so the progression of phases in the digram below should be read right to left.



- Cover all the magnetic Moon phases with small Post-it® notes so they are not visible.
- Set up the Starfield Cylinder **with all the Moon phases attached**. Set the tilt of the star projector to your latitude. Set the **New Moon** so that it is on the western horizon.

Procedure

Directions/notes to the teacher are bulleted or in parenthesis. Suggested script is italicized.

- Make sure that the students are seated comfortably around the edge of the dome. Dim the lights and bring up the starfield with all the moon phases covered with Post-it® notes so that they cannot yet be seen. Begin with the star projector lamp on high so that your students can clearly see the stars; later you may wish to dim the light a bit to help prolong the life of the projector bulb, but don't do this until your students are fully dark adapted.

The sky you are viewing is this season's sky just after twilight. Can you see the Moon?

(It's not visible.)

Where is it?

(Wait for responses.)

The Moon is not always visible in the sky. Sometimes you won't see it, even if you stay up all night long. Where would the Moon be on a night like that?

(It's in the day sky, near the Sun. When the Moon is between the Earth and Sun in its orbit it cannot be seen. This is a New Moon.)

As the Moon moves in its orbit, out from between the Earth and Sun, it will begin to appear in the early evening western sky as a thin crescent.

- Remove the Post-it® from in front of the first waxing crescent Moon to unveil it to the students. Remember that the Moon moves left or eastward as it progresses in its orbit, so rebove the Post-it® note from the Moon phase to the left of the New Moon, but do not tell the students yet the direction of travel.

How does the Moon move? Where does it go?

(Wait for responses.)

The Moon revolves around Earth once every 29.5 days in relation to the Sun. You may notice that this is about the same length of time as a month. This is actually where that unit of time originated; a month is derived from a "moonth." A moonth *was the length of time from one Full Moon and the next (or from one New Moon to the next). So if the Moon revolves around Earth, then it must change positions in the sky.*

- Point out the four cardinal points: North, East, South, and West.

Here are the four directions of the compass, in which direction do you think the Moon moves?

- Take a verbal vote. Tell them they can only vote once, then ask them which direction they think it's moving towards, have them say "I do" when you state the direction that they believe is the proper motion.

North? East? South? West? Most of you think that the Moon moves _________ through the sky. Let's see where it would be about two days from now just after twilight.

- Place the Post-it® note back over the first crescent Moon, remove the Post-it® from the next thicker crescent Moon which is left or eastward of the previous phase.

Which direction did it move? Let's vote again. Remember you can only vote for one direction. North? East? South? West?

- If it is not clear to them, do it again. Cover the second thicker Crescent Moon and uncover the First Quarter Moon. By now the direction of motion should be obvious.

That's right. The Moon moves generally in an easterly direction. The distance we are moving the Moon is for about than two days time span. Now let's see if you can predict where the Moon would be two days from now just after twilight.

- Trace the path of the Moon from the first thin crescent location past the present location and have the students tell you when to stop for where it will be in two days, just after twilight.
- When you come to a general consensus, either circle the spot with your pointer as you unveil the next Moon phase location, or (if your group is older) locate the spot in relation to the background stars so they can keep a track of the position themselves without using the pointer as a marker — this would be similar to what one would have to do in the real sky over the course of several days. Now, cover the First Quarter Moon back up with the Post-it®, and unveil the next phase — Waxing Gibbous. If their prediction was correct, great! If they're still off, have them make a prediction again for the next phase. Students usually get it right after a couple of tries.

  Note

  It is important at this point to keep covering up the phases after you go by them. You only want one image of the Moon visible at a time because of the next activity.

- At this point, you should have a Gibbous Moon visible somewhere in the southeastern or eastern sky. Your students should feel pretty confident that the Moon is moving eastward through the stars.

All the views of the Moon we've witnessed have occurred over a series of nights, each taking place just after twilight. So now that we have figured out how the Moon moves, let's pretend that we have decided to go indoors and spend the next couple of hours watching television or doing homework.

- Dim the stars out of sight and bring the house lights up just enough so it's not pitch black. Move the diurnal motion of the starfield for about 10 seconds to simulate the passing of 1-2 hours of time.

I've dimmed the sky because while you are inside you're not paying attention to the Moon or the stars. About two hours later, just before bed, you decide to check out the Moon again. When you go back outside (turn the stars back up again) this is what you see. Has anything changed?

- The students should now quickly note that the Moon they saw earlier in the eastern sky has moved westward while keeping the same phase. For younger students this presents a conundrum that they may not be developmentally ready to understand and you might want to leave this part out.

Earlier we clearly showed that the Moon moves easterly through the stars, yet now it seems to have moved westward. How has this happened?

- Wait for responses. The students may figure it out, but if they need help have them notice that the stars have moved westward too.

The Moon is still really only moving toward the east, but we are on a moving object called Earth, that is rotating eastward faster than the Moon revolves. Essentially, you on the rotating Earth passing the revolving Moon. To prove it's Earth moving and not the Moon, notice that the stars have moved westward too. It is all caused by Earth's rotation. In the planetarium we can make this spinning more noticeable by speeding it up. Watch and you'll see the stars and the Moon moving together towards the west.

- Turn on diurnal motion.

Notice that the Moon is not moving westerly through the stars, instead the Moon and the stars are drifting westerly together as Earth moves rapidly towards the east. Remember how the Moon's phase had changed with the eastward motion. Is it changing now as it and the stars drift west?

(No.)

- Stop diurnal motion.

How did the phases change during the roughly two weeks of easterly motion we tracked earlier?

(They should note that it had grown larger each time.)

The growing phases of the Moon are referred to as the ***Waxing phases****. The small "fingernail" shaped Moon is called a* ***Waxing Crescent****. The Half Moon is actually called the* ***First Quarter Moon****.*

Note to Teachers

This concept is often confusing to many students. Why do we call a Half Moon a Quarter Moon? There are two ways to answer this. First explain that the Moon at this phase is only a quarter — one-fourth — the way around its orbit of the Earth. Second, you can also explain that when you see half a Moon, you are only seeing half of the near side. Remember that there are two more "halves" on the backside too!)

The oval shaped Moon is called a ***Waxing Gibbous Moon****.*

- Unveil these previous phases again as you list them and leave the Post-it® note off.

Let's see if you can predict what phase will be next.

- Unveil the next Moon phase. Depending where you left off it should be either a Waxing Gibbous or a Full Moon. If it is a Waxing Gibbous, have them predict again until you get the Full Moon. As you unveil the new positions and phases it is helpful at this point to leave the previous phases visible so they can see the phase progression. This will reinforce the Moon's easterly movement through the stars and clearly show the growing size of the Moon.

Now we see the Full Moon, what phase will come next? Can the Moon continue to grow and get bigger?

(Wait for responses. They will probably be able to predict that it will start getting smaller again.)

After the Full Moon the phases start getting smaller. When the Moon is decreasing in size, it is said to be "Waning." What waning phase comes next after the Full Moon? Waning Crescent? Last Quarter? Gibbous? Of course the order is reversed, Gibbous, then Last or Third Quarter, to Crescent, and finally back to the New Moon where we started.

- Make sure to go through these phases (quickly or slowly depending on your group's understanding) until you return to your starting point at the New Moon phase.

STARLAB Lesson 2:
Phases and Eclipses.

Objectives

- To discover how and why the Moon's motion creates the changing phases.
- To learn the names of the Moon phases.
- To understand the causes of eclipses.

Lesson Length

30 minutes. (STARLAB Lessons 1 & 2 can be easily combined into a complete and complimentary one hour session.)

Suggested Grade Levels

This lesson can be modified from a simplified version for as young as third grade to a more fully developed lesson for middle school students.

Integrated Subjects

- Science
- Astronomy
- Geometry
- Physics
- Time
- Maps

Processing Skills

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- Read the supporting material provided in this lesson plan and curriculum guide.
- Set up the Moon Cylinder so the cover hides the sidewall moon phase images of the cylinder. Note the clear notch at the top of the cover. Place it between the im-

Materials

- STARLAB Portable Planetarium
- Moon Cylinder and velcro, notched sidewall cover
- A small piece of transparent red acetate to cover the Full Moon phase to illustrate a Lunar Eclipse. Be sure to use a red that is not so dark that it makes the Moon disappear!

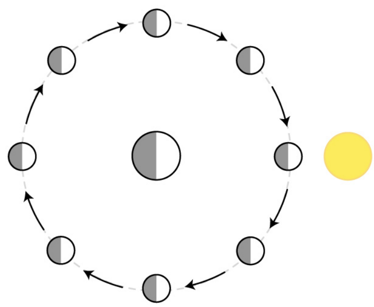

Figure A. This view is as seen from below Earth's south pole. To make this diagram match precisely what you see in the dome, hold the diagram over your head.

age of the solar eclipse and the Waxing Crescent Moon. Be sure that the cover slides easily around the cylinder with your hands.

- Do not tilt the projector.

Procedure

Directions/notes to the teacher are bulleted or in parenthesis. Suggested script is italicized.

- Make sure that the students are seated comfortably around the edge of the dome. Dim the house lights. Bring up the light inside the Moon Cylinder. Directly overhead the students will see a diagram of the Earth (as seen from below the south pole), Sun and Moon. Earth will be in the center directly overhead. The Moon's orbit will be clearly shown circling Earth with a series of small Moon images located at eight intervals around the orbit. Off to one side will be a yellow Sun. The cover just outside the perimeter of this diagram hides actual images of each lunar phase.
- What your students will initially see is this (remember that this diagram should be viewed as though it is directly over your head as it will be in the planetarium. (See Figure A.)

Part 1: Moon Phases

Why are the Earth and Moon shown with one side white and one dark?

(Wait for responses.)

The light sides represent the sides of the Earth and Moon that are illuminated by the Sun. The darks sides face away from the Sun and represent the nighttime sides of Earth and Moon. How long does it take for the Moon to orbit around Earth?

(Wait for responses.)

When we measure that motion in relation to the Sun it takes 29.5 days, nearly a month. This is how the length of time known as a month came to be. A month is derived from a "Moonth"— the time from one Full Moon to the next Full Moon.

(If this lesson is being combined with Lesson 1, then this last bit of information should be dropped.)

- Point out the Moon at the point directly between Earth and the Sun.

What would the Moon look like at this point in its orbit?

(Wait for responses. They should be able to determine that the Moon is not visible from Earth at this point.)

The only part of the Moon's surface that we can easily see is the sunlit side. Since at this point in its orbit none of the sunlit side faces Earth, it is not visible in the sky.

- Move the students' attention to the next Moon along the orbit following the orbital arrow to the left.

In this diagram it takes the Moon a little more than three days to move from the New Moon location to this spot. The portion of the Moon that we can see from Earth is always the part that is inside the large circle representing the Moon's orbital

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[1] *As you move the cover on the cylinder counter-clockwise, you may note that when you look up at the diagram the Moon moves clockwise. This can be a source of confusion which is caused by looking at the same motion from the two different perspectives of up and down.*

path. What will the Moon look like when it's at this point in its orbit as viewed by someone standing on Earth?

(Wait for responses.)

- Once they have made their predictions, slide the cover counter-clockwise[1] to reveal the Waxing Crescent Moon which is directly beneath the phase point of the orbit that we have been discussing. What they should see is this (Figure B):
- Point out that the thin Crescent Moon corresponds to the small sunlit part of the Moon that faces Earth in the diagram. You might also call their attention to the fact that you can just barely see the outline of the night side of the Moon.

Notice that you can just barely see the night side. It is very faintly lit by something called Earthshine. Earthshine is sunlight reflecting off Earth, bouncing to the Moon, and lighting it up slightly, just as a Full Moon lights the Earth with its light.

- Now continue on around the Moon's orbit and see if the students can identify the Moon's appearance at each spot along its month-long path. After each guess, simply rotate the cover to reveal the next phase.
- Be sure to discuss the difference between a Waxing Moon and a Waning Moon. Explain that while the Moon is getting larger it is waxing; when it is diminishing, it is waning.

As the Moon waxes, it moves left, or eastward, away from the setting Sun. This means that the Waxing Moon is seen best in the evening skies after sunset. The Full Moon is exactly opposite the Sun. This means it will rise in the east exactly when the Sun sets in the west. The next morning when the Moon sets in the west, the Sun will then rise in the east. On the other hand, after the Full Moon, the Moon begins to wane or get smaller in phase. It rises later and later at night and is therefore best seen during the hours just before sunrise.

- When you arrive back at the New Moon phase, stop sliding the cover before it gets to the eclipse image. They should be able to guess that the Moon is not visible at this point in the orbit, just as they saw when they started.

Part 2: Eclipses

What would happen if the Earth, Moon and Sun lined up exactly in a perfectly straight line?

(Wait for responses. Someone will likely guess that this will cause an eclipse of the Sun. Move the cover to reveal the Solar Eclipse image.)

What is the black disk in front of the Sun?

(Wait for responses.)

It's the Moon, and the light shining around it is sunlight illuminating the Sun's corona or outer atmosphere. Do we have an eclipse every New Moon? Why?

(Wait for responses.)

We don't have an eclipse with every New Moon because the Moon's orbit is tilted slightly off the plane of Earth's orbit around the Sun. The Moon usually passes either just above or below the Sun. When the two orbits align an eclipse occurs. This generally happens only twice a year.

The Earth, Moon, and Sun have a unique configuration. Consider the fact that the Sun is four hundred times farther from Earth than the Moon, and that the Sun's

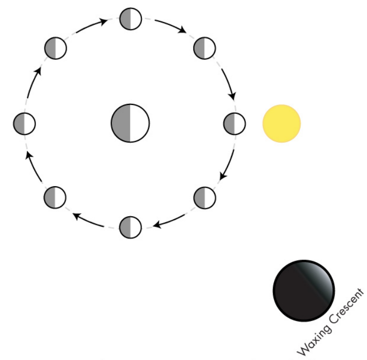


Figure B. This view is as seen from below Earth's south pole. To make this diagram match precisely what you see in the dome, hold the diagram over your head.

diameter — by sheer coincidence — is four hundred times larger than the Moon's diameter. This coincidence makes the Sun and Moon appear to be the same size in the sky. Nowhere else in the Solar System does this precise an alignment occur. Such an eclipse, as we routinely see here on Earth, is unique to our planet.

Note

Whenever you discuss eclipses with students, it's always important to stress the fact that looking towards the Sun, eclipse or not, is dangerous to your eyesight. If any part of the Sun's disk is visible you should never look directly at it. ***Sunglasses do not make it safe to look at the Sun****.*

- Now point towards the Full Moon.

What would happen if a similar alignment between Moon, Earth, and Sun were to occur at this point in the Moon's orbit?

(Wait for responses.)

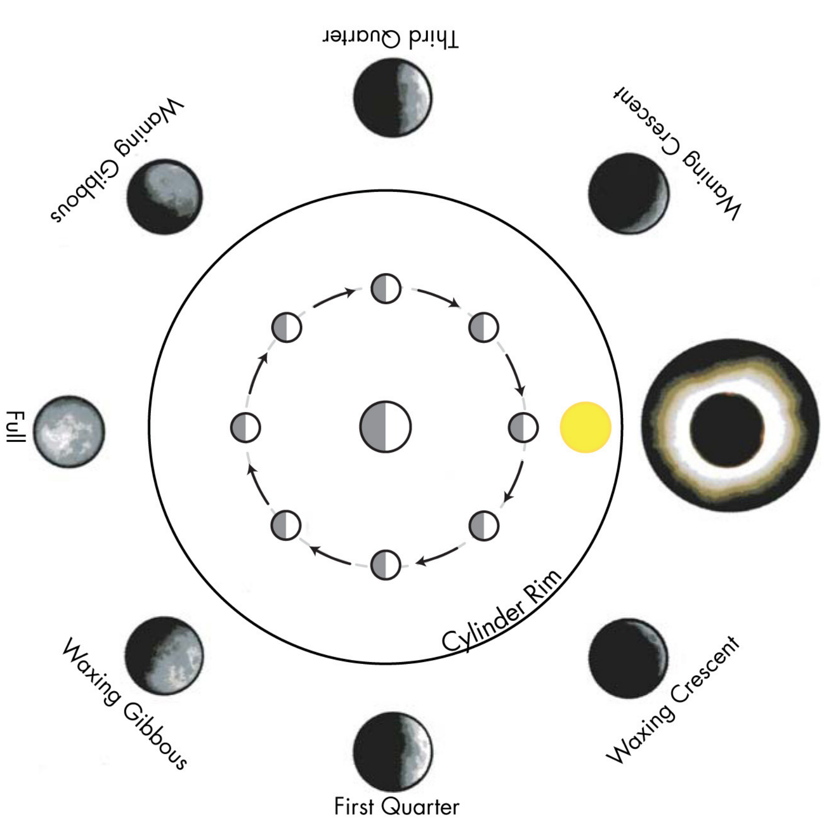
The answer is a lunar eclipse. A lunar eclipse occurs when the Full Moon moves directly into Earth's shadow. As the Moon enters the shadow, it appears to have a growing bite nibbled away from its bright disk. What will the Moon look like when the it is totally engulfed by Earth's shadow?

(Wait for responses. They will probably guess that the Moon will disappear from view. That's not what happens.)

Even though the Moon looks like it will totally disappear, instead, it turns red.

- At this point tape the red acetate film over the image of the Full Moon to give it a red coloration.

Figure C. This view is as seen from below Earth's south pole. To make this diagram match what is seen in the dome, please hold the diagram over your head.



The red color is caused by Earth's atmosphere bending some of the sunlight around the edge of the planet. It fills Earth's shadow with faint red light. The reason it is red is the same reason the sunset is red. Shorter wavelengths of light, such as blue, scatter easily — that's why the sky's blue. Longer wavelengths of light, such as red and orange, tend to bend a bit, but not scatter so completely. This slight bending of the reds and oranges fills Earth shadow with this light and turns the darkened Moon a slight crimson hue.

A lunar eclipse is not dangerous to observe and cannot damage your eyesight.

The diagram (see Figure C) shows the complete set of images used in this lesson.

STARLAB Lesson 3:
Topography – What's on the Moon?

Objectives
- To learn the visible features on the Moon's surface.
- To learn the names and histories of a few craters and maria.
- To learn how these features (craters, maria, rilles, etc.) were formed.
- To determine relative ages.
- To compare the near side of the Moon to the far side of the Moon.
- To locate the Apollo landing sites.

Lesson Length

60 minutes, but it can be easily broken up into smaller parts.

Suggested Grade Levels

This lesson can be modified from a simplified version for as young as third grade to a more fully developed lesson for middle school students.

Integrated Subjects
- Science
- Astronomy
- Physics
- Maps
- Space Exploration
- History

Processing Skills

Listening • Observing • Interpreting • Discovering • Reasoning • Making Hypothesis and Conclusions

Preparation
- Read the supporting material provided in this lesson plan and curriculum guide.
- Be sure the top of the cylinder is covered.
- Set the cylinder so that the near side images of the Moon are clearly visible when it is uncovered. Begin with everything covered using a sidewall covering (see note). Allow just the Full Moon phase to be visible from the Moon phases around the top of the cylinder walls (this phase is aligned to be directly above the near side unlabeled large Moon image).

  Note

  You can make a sidewall covering with four sheets of paper cut to 7 3/4" x 11". Tape them end to end and wrap them around the cylinder to cover the four large images from view. Black paper works best.

Procedure

Directions/notes to the teacher are bulleted or in parenthesis. Suggested script is italicized.

Materials
- STARLAB Portable Planetarium
- Moon Cylinder and magnetic felt cylinder top cover and Velcro sidewall cover

- Make sure that the students are seated comfortably around the edge of the dome. Fade the houselights and bring up the star projector showing only the Full Moon from the phase sequence along the top of the cylinder walls.

Part 1: Basic Features using the Small Image of the Full Moon

- Point out the small Full Moon.

Does the Moon appear to be the correct size compared with what you see in the real sky outside?

(Wait for responses. It should be clear that the image is larger than it appears in the sky to the unaided eye.)

The view you are seeing is similar to what may be seen with a pair of binoculars.

(This can be a good take off point to discuss the Moon's apparent size.)

Does the Moon change its size in the real sky?

(You may get answers suggesting that the Moon appears larger near the horizon. If you don't get that suggestion, suggest the idea yourself.)

Did you ever notice that the Moon looks bigger when it's near the horizon? Is it really bigger when it's low in the sky? No, the Moon is not any bigger when it's low in the sky. This is simply an illusion, perhaps our minds trying to make sense of seeing the Moon looking relatively large near distant trees or buildings. If you measure the width of the Moon in the sky with your finger, you'll discover that it's the same diameter no matter where it appears in the sky.

Look at the Moon again. What do you see?

- Point out the gray colored seas or maria.

What are these dark areas?

(Most students believe these to be craters.)

These dark areas on the Moon are not craters but instead something called maria, which is an old Latin word which means "seas" or "oceans." Each individual dark area is called a "mare." Does this mean that there is water there? No, it means that long ago some astronomers thought there was water there. We now know that the maria are actually vast plains or flatlands composed of hardened lava floes of iron rich basalt. Volcanoes erupted onto the lunar surface more than 3 billion years ago. Without a telescope, or at least binoculars, it's nearly impossible to see any craters, but it's easy to see the maria.

- Point out the white areas that surround the maria.

What are these parts of the Moon called? They're called the highlands. What do you think you might find in a region known as the ***highlands****? The highlands are areas with mountains, hills, deep valleys, and many craters. Notice that the highlands look white while the maria look gray. The color difference is because of the composition of the rocks. The maria are composed primarily of volcanic basalt, which hardens into a dark colored rock. The highlands are composed of older, lighter colored rocks (largely anorthosite — a calcium-aluminum silicate).*

When people look at the darker maria against the lighter highlands, they often use their imaginations to see pictures on the Moon, similar to how we see constellations in the stars. The most famous Moon picture is the "Man in the Moon."

- Point out the Man in the Moon. You can also explain how people have seen many different pictures in the same way. Here are a few that you can choose from to show your students:


Man in the Moon


Woman in the Moon


Jump-Roping Girl


Sword Fighter


Frog


Ant


Rabbit


Make Your Own

Part 2: The Large Moon Image: Maria

To understand surface features on the Moon more clearly, let's look at it a bit closer.

- At this point remove the side cover, revealing the larger view of the Moon.
- Review the maria and highlands.

Let's look a little closer at the maria. Notice how smooth they look. Some maria are very old impact basins formed from giant craters that have filled with lava. Other maria were simply low regions that were filled from volcanic eruptions. Since the lava was liquid, it filled these areas to a level surface and then hardened. This gives them a smoother appearance.

While there are some ridges and wrinkles in the maria, it is much smoother than the highlands. Look at the labeled Apollo landing sites. There are six sites marked by small triangles, labeled Ap11 through Ap17. If we look at the six landing sites you will see that as the landings proceeded, each successive landing became more challenging in its terrain. Why this would be? Why would they want to chance landing in the more rugged highlands during the later trips?

(Wait for responses.)

Scientists are cautious people, but they are also curious. It made sense to pick a safe flat spot for the first landing. As scientists and engineers became more acquainted with the peculiarities of landing on the Moon's surface, they became more confident about exploring more difficult and perhaps more interesting terrain.

Look at the labeled image of the Moon and notice the names given to the maria. Ocean of Storms, Sea of Rain, Sea of Serenity, Sea of Tranquility, Sea of Cold, Sea of Crises, Sea of Fertility, Sea of Vapors, Sea of Moisture, Sea of Clouds, Sea of Knowledge, Sea of Foam, Sea of Waves.

Smaller areas of such volcanic floes are labeled as bays (sinus), lakes (lacus), and *marshes (palus). Find such areas as Bay of Rainbows, Bay of Dews, Central Bay, Bay of Heat, Bay of Love, Bay of Success, Lake of Fear, Lake of Excellence, Lake of Dreams, Lake of Death, Marsh of Epidemics, Marsh of Sleep, and the Marsh of Decay.*

(There are even more that are not labeled such as the Lakes of Suffering, Joy, Tenderness, Hope, Persistence, Hate and Good. Also there are lakes for all four seasons: Summer, Autumn, Winter and Spring.)

Notice that the names used to designate seas, bays, lakes, and marshes all relate to either water — in the form of weather or the sea — or human conditions, especially of the mind, such as knowledge, emotions, and states of being (such as sleep, success and death). These connections were made in ancient times when early astronomers noted the Moon's affect on ocean tides, cycles of animals and seasons, and people's state of being. Even today many still believe that people act crazier during a Full Moon. When someone acts crazy we say they are acting "loony. " Even people in love are said to be "moonstruck."

- Ask the students if they can think of other terms and sayings that have their origins with "luna" or the Moon. Examples: a month, a lunatic, shoot-the-Moon, the cow jumped over the Moon, and even to "moon" someone!

Part 3: The Large Moon Image: Craters

- Move the cylinder to bring the crater map of the Moon into central view.

Now look at the craters. There are more than 30,000 craters visible in a telescope from Earth. Craters are formed when a meteoroid or rock from space collides with the Moon. Craters have distinct parts: a hole, a rim, exterior rays, and sometimes an interior mountain. These features can be easily understood by throwing rocks in a lake. When you throw a rock into a lake what happens?

(Wait for responses.)

Splash! Is there a splash when a rock hits the Moon?

(Wait for responses.)

Yes! On the Moon, it's a splash of rock, dirt, and debris. It goes flying out from the point of impact and falls down to the Moon's surface. We see the remains of the splash when we see the rays or ejecta that radiate out from some craters. The more prominent the rays can be seen, the younger the crater. After the splash when the rock hits the lake what do you see next?

(Wait for responses.)

Ripples! Is there anything about a crater that reminds you of the ripples? The crater rim is the solid remains of the ripple. In the lake the ripples move out as circular waves and dissipate in the liquid water. On the solid Moon, the ripple moves out from the point of impact. When the energy dissipates, the circular wave stays where it is — creating the rim.

Unlike a stone tossed into a lake, a rock hitting the Moon creates tremendous energy. The heat of impact vaporizes the meteorite, creating a huge explosion. It blasts a crater ten times bigger in diameter than the object itself! The bottom of the crater rebounds back upwards after the pressure of the explosion creating the central mountain within the crater.

The craters were named more recently than the maria. Why didn't ancient astronomers name the craters?

(Wait for responses.)

The answer is that the craters can only be clearly seen with a telescope. The ancients had no telescopes.

One of earliest maps to include craters was published in 1651 by the astronomers Riccioli and Grimaldi. They named the craters for famous astronomers and philosophers, generally in a chronological order from north (older) to south (more recent). This is a very general rule that doesn't always hold true. These two men, however, were not without their prejudices. Being traditionalists, they both still believed in an Earth-centered universe and neither liked the idea of a Sun-centered universe. They both greatly admired Tycho, another traditionalist, and gave him the brightest and most distinct crater in the southern highlands. They despised Galileo as a heretic and gave him a small crater that is difficult to see, even though Galileo was the first to see and document craters on the Moon. They grudgingly gave Copernicus and Kepler — both followers of the Sun-centered universe theory — distinct craters. However, with a note of symbolism the craters of Galileo, Kepler, and Copernicus are all found in the Ocean of Storms, a subtle suggestion that the craters' namesakes were lost in controversy at the time. You might find it interesting that Riccioli and Grimaldi gave themselves very large craters. The crater Grimaldi also holds the status of having the darkest color of any crater on the Moon (followed closely by Plato).

Part 4: The Large Moon Image: Determining Relative Ages

Now let's go back to the picture of the Moon without labels. Notice the distribution of craters on the Moon's surface. Where do you find the most craters?

(Wait for responses.)

In the highlands! Do you think that meteorites hit the highlands more often than the maria?

(Wait for responses.)

No. Rocks have hit the Moon evenly, all over its surface. So why are there more craters in the highlands?

(Wait for responses.)

The answer is that the highlands are older than the maria. The volcanic floes happened after the heavy bombardment of the Moon's surface by meteoroids early in the history of the solar system. The lava covered low areas, and filled a few large craters, such as the Sea of Rain and the Sea of Serenity. This tells scientists that the maria are younger than the highlands. Also, maria with more craters are believed to be older than maria with few craters.

The relative age of craters can be determined too. In the central highlands you will find the large crater Albategnius with the smaller crater Klein superimposed upon its side. Which crater is older? Why?

(Wait for responses.)

Albategnius is older. If the smaller Klein had happened first, the larger Albategnius *would have destroyed it. Craters that appear on top of or partly imposed over other craters are always younger.*

Just west of Albategnius is a string of three fairly large craters: Ptolemaeus, Alphonsus, and Arzachel. These three craters' relative ages are known as well, even though they do not overlap. Age in this example is more difficult to determine. Here we look for the signs of erosion and size. Erosion does occur on the Moon, but very, very slowly; it is largely caused by the constant bombardment of solar particles and energy. Younger craters show less erosion, this gives them steeper, taller rims and deeper centers. Older craters have lower rims and are much shallower. Another general rule is that larger craters are usually older than smaller craters, because in the early solar system there was more large debris floating around than there is now. Look at these three craters, which one do you think is youngest? Oldest?

(Wait for responses.)

Ptolemaeus in the north is oldest, Arzachel in the south in youngest. Not only is Ptolemaeus the largest of the three, but its rim walls are smaller and less distinct, and the crater appears to be shallow. Arzachel is the smallest of the three, it has tall sharp looking rim walls and it appears deeper than the other two craters.

Another age indicator is the presence of bright rays. Rays are believed to be the splash of materials thrown from a meteorite impact. Rays fade with time, so brighter rays designate younger craters. In the south the dominant crater is Tycho, the brightest crater on the Moon. The crater itself is 85 kilometers/53 miles in diameter, but its impressive ray system stretches 1,500 kilometers/930 miles out from the crater. Its sharp features, relatively small size, bright color, and impressive ray system (the splash) suggests to scientists that it may be the youngest major crater on the Moon, only 100 million years old!

Do you see any other craters with distinct ray formations?

(Copernicus, Kepler, Aristarchus, Byrgius, Fernerius, and Stevenius.)

The small crater named Messier has a ray going out in only one direction. What does that tell you about the impact that formed it?

(Wait for responses.)

Part 5: The Large Moon Image: Mountains, Valleys, Rilles, and Domed Volcanoes

If you look around the Sea of Rain you will notice some of the Moon's most prominent mountain ranges. Beginning in the south we see the Carpathian Mountains, moving counterclockwise we find the Apennine Mountains — the largest range on the Moon — then the Caucasus Mountains, and the Alps. Here again we find a system of naming. In this case the mountain ranges on the Moon are named after mountain ranges on Earth. Why do you suppose there are no Andes, Appalachian, or Rocky Mountain ranges on the Moon?

(Wait for responses.)

Because they were named before Earth's western hemisphere was fully explored.

Look a little more carefully and you will find places where spectacular landscapes would be found on the Moon. In the midst of the Alps is a long deep valley, conveniently named the "Alpine Valley." It is 180 kilometers/112 miles in length and *bordered by the Alps, which reach average heights of 2,000 meters/6,500 feet. On the east side of the Alpine Valley where it meets the Sea of Rain, we find Mount Blanc, the tallest mountain in the lunar Alps reaching 3,600 meters/12,000 feet in altitude.*

Sitting alone like an island in the Sea of Rain, we find Mount Piton and just west is Mount Pico. Both mountains have altitudes of nearly 2400 meters/8,000 feet. When we look at the Alps we found them punctuated by two distinct craters: Plato, a lava filled crater in the west; and Cassini in the east, an old crater with two small craters inside its rim.

Head south from Cassini and we find the Apennine Mountains, the most impressive mountain terrain visible on the Moon. Impressive peaks such as Mounts Hadley, Bradley, Huygens, and Ampieres rise above the Sea of Rain and the Marsh of Decay to heights of 5,400 meters/17,700 feet. It was near Mount Hadley that Apollo 15 landed. The Apennine Mountains have very steep slopes descending toward the Sea of Rain, while the backsides of these mountains descend much more gradually to the Sea of Vapors.

South of the Sea of Vapors we find Middle Bay, a small mare with faint lines running north/south connecting it with the Sea of Vapors, and east/west connecting it with the Sea of Tranquility. These lines are called rilles, which are grooves or cracks in the Moon's surface. Many of them are believed to be the remains of lava riverbeds. While rilles are found all over the Moon, this is one of the most extensive networks of rilles to be found.

Head due west across both the Sea of Rain and the Ocean of Storms, just beyond the crater Marius, we find the dome shaped Hills of Marius. Just north of the Hills of Maris is another domed mountain called Mount Rumker. All these hills are believed to be the result of volcanic activity on the Moon, either old volcanoes themselves or in some cases simply domes of rock raised into mountains by underground magma.

Jumping further south, at the eastern edge of the Sea of Clouds, you will find a north/south line that is clearly visible. This is known as the "Straight Wall." It is a fault line ridge, or rupe with a height of 300 meters/1,000 feet and a length of 110 kilometers/68 miles. It is a very distinctive feature in small telescopes.

These features represent some of the more interesting features found on the Moon. Perhaps these are some of the spots that will one day be set aside as National Parks on the Moon!

Part 6 The Large Moon Image: The Far Side of the Moon

- Now turn the cylinder to bring up the image of the Moon's far side.

How is the Moon's far side different from the familiar near side?

(Wait for responses.)

Notice that there are only a few small maria or seas on the far side. Why should that be? Scientist hypothesize that the Moon's crust is thinner on the Earth side and that made it easier for volcanic eruptions to occur on the near side. It has been considered that the Moon's core may not even be in the center of the Moon, but instead a bit closer to the near side. This might be a result of that side always facing Earth and the continual tug of Earth's gravity in that direction. Notice that the names tend to be more modern and often Russian. Why?

(Wait for responses.)

We had never seen the far side before spacecraft orbited the Moon in the 1960s, and the first spacecraft to view the far side were from the Soviet Union.

Conclusion

All the features we've seen — craters, mountains, volcanic domes, rilles, and rupes or cliffs created by faults — should tell us that our Moon is a place with a very active geological past. There were once thousands of violent explosions as it was bombarded from space. It has had volcanoes erupting, and lava surging across the landscape filling lowlands and vast craters. We see the very riverbeds where that lava once flowed. We also can see huge cliffs, hundreds of kilometers long, where the surface has either sunken or risen up due to internal pressures.

Looking back at the Full Moon image without any labels, we find a much more detailed object than we started with. Yes, everything we've talked about has always been there, but with a little examination and understanding, it helps us see the Moon better. It is a place with a complex terrain. We find impact craters, mountains, volcanoes, vast plains of lava, and a history of naming that contains interesting anecdotes and stories.

I hope that this presentation has helped you understand a little better what you're seeing when you look up at night and see the Moon overhead.

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