UNIT 3

<u>Satellites</u>

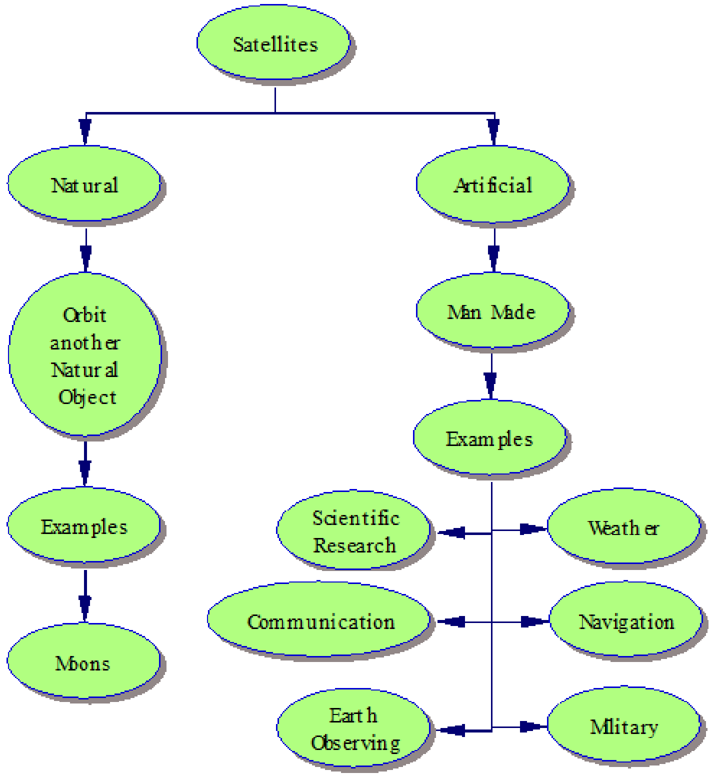
3.1 Artificial Satellites

3.2 Lunar orbit (phases, eclipses, &tides)

3.3 Lunar surface features and origin

Artificial Satellites Reading

Satellite is a general term used to describe any object that revolves around another in space. We are a satellite of our sun, Sol, and our Moon, Luna, is a satellite of Earth. As you can see in the chart, satellites can be both natural, like Luna, our moon or they can be man-made or artificial.



As you have already known, humans have been able to put many different artificial satellites into space. The Hubble Space Telescope, GPS navigation, XM Radio, Google Maps, and even your cable television would not be possible if it were not for man-made satellites!

In short, an artificial satellite is a manufactured object that continuously orbits Earth or some other body in space. Almost all artificial satellites orbit Earth, however we do have satellites orbiting Mars and have at some point had satellites that have orbited all 8 planets. Satellites can be classified in one of two ways; how they travel in their orbit, and what it's purpose is. The three pathways are geo-synchronous, and polar orbit (also known as low orbit). The common types of satellites include military (spy) and civilian Earth observation satellites, communication satellites, navigation satellites, weather satellites, and research satellites.

Question: What are the different paths and types of artificial satellites and what are their life-cycles?

Background: *(write a few things that you already know pertaining to about the question above)*

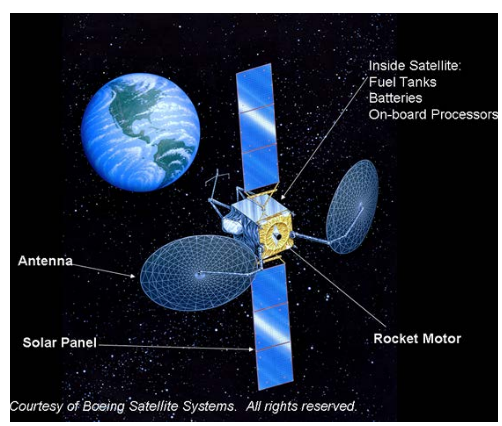
Vocabulary:
Natural satellite
Artificial satellite

Materials: This reading

Procedure: Read through the following passage.

Satellites

Satellite orbits vary greatly, depending on the purpose of the satellite, and are classified in a number of ways. Well-known classes include low Earth orbit, polar orbit, and geostationary orbit. Artificial satellites also have orbited the moon, the sun, asteroids, and the planets Venus, Mars, and Jupiter. Such satellites mainly gather information about the bodies they orbit. Artificial satellites differ from natural satellites, which are natural objects that orbit a planet. Earth's moon is a natural satellite.



Types of Artificial Satellites

Artificial satellites are classified according to their mission. There are six main types of artificial satellites: (1) scientific research, (2) weather, (3) communications, (4) navigation, (5) Earth observing, and (6) military. Scientific research satellites gather data for scientific analysis. These satellites are usually designed to perform one of three kinds of missions. (1) Some gather information about the composition and effects of the space near Earth. They may be placed in any of various orbits, depending on the type of measurements they are to make. (2) Other satellites record changes in Earth and its atmosphere. Many of them travel in sun-synchronous, polar orbits. (3) Still others observe planets, stars, and other distant objects. Most of these satellites operate in low altitude orbits.

Scientific Research

Scientific research satellites can also double as weather or Earth observing satellites and are used to collect data on a wide variety of things. Space telescopes and space craft such as the space shuttle and the International Space Station are also included in this category. The ISS as it often referred to is the largest man-made satellite in space and is easily seen in the night sky as it passes overhead.

Weather

Weather satellites help scientists study weather patterns and forecast the weather. Weather satellites observe the atmospheric conditions over large areas. Some weather satellites travel in a sun-synchronous, polar orbit, from which they make close, detailed observations of weather over the entire Earth. Their instruments measure cloud cover, temperature, air pressure, precipitation, and the chemical composition of the atmosphere. Other weather satellites are placed in high altitude, geosynchronous orbits. From these orbits, they can always observe weather activity over nearly half the surface of Earth at the same time. These satellites photograph changing cloud formations. They also produce infrared images, which show the amount of heat coming from Earth and the clouds.

Communication

Communications satellites serve as relay stations, receiving radio signals from one location and transmitting them to another. A communications satellite can relay several television programs or many thousands of telephone calls at once. Communications satellites are usually put in a high altitude, geosynchronous orbit over a ground station. A ground station has a large dish antenna for transmitting and receiving radio signals. Sometimes, a group of low orbit communications satellites arranged in a network, called a constellation, work together by relaying information to each other and to users on the ground. Countries and commercial organizations, such as television broadcasters and telephone companies, use these satellites continuously.

Navigation

Navigation satellites enable operators of aircraft, ships, and land vehicles anywhere on Earth to determine their locations with great accuracy. Hikers and other people on foot can also use the satellites for this purpose. The satellites send out radio signals that are picked up by a computerized receiver carried on a vehicle or held in the hand.

Earth Observing

Earth observing satellites are used to map and monitor our planet's resources and ever-changing chemical life cycles. They follow sun-synchronous, polar orbits. Under constant, consistent illumination from the sun, they take pictures in different colors of visible light and non-visible radiation. Computers on Earth combine and analyze the pictures. Scientists use Earth observing satellites to locate mineral deposits, to determine the location and size of freshwater supplies, to identify sources of pollution and study its effects, and to detect the spread of disease in crops and forests.

Military

Military satellites include weather, communications, navigation, and Earth observing satellites used for military purposes. Some military satellites, often called spy satellites, can detect the launch of missiles, the course of ships at sea, and the movement of military equipment on the ground.

Satellite Orbits

There are literally an infinite number of possible orbits for an Earth satellite. While there are special orbits that are designed for specific purposes, two general classes of orbits have come into wide spread use for meteorological observations of the Earth: geostationary orbits and sun-synchronous near-polar orbits. In spite of the qualifiers, the sun-synchronous orbits are normally just referred to as polar orbits.

A satellite remains in orbit because of a balance between the satellite's velocity (speed at which it would travel if were traveling in a straight line) and the gravitational force between the satellite and the parent object (Earth is mainly the parent object). Were it not for the pull of gravity, a satellite's velocity would send it flying away from its parent object in a straight line. But were it not for velocity, gravity would pull a satellite back to earth.

To help understand the balance between gravity and velocity, consider what happens when a small weight is attached to a string and swung in a circle. If the string were to break, the weight would fly off in a straight line. However, the string acts like gravity, keeping the weight in its orbit. The weight and string can also show the relationship between a satellite's altitude and its orbital period. A long string is like a high altitude. The weight takes a relatively long time to complete one circle. A short string is like a low altitude.

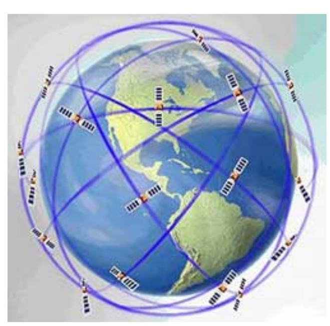
Geostationary Satellites

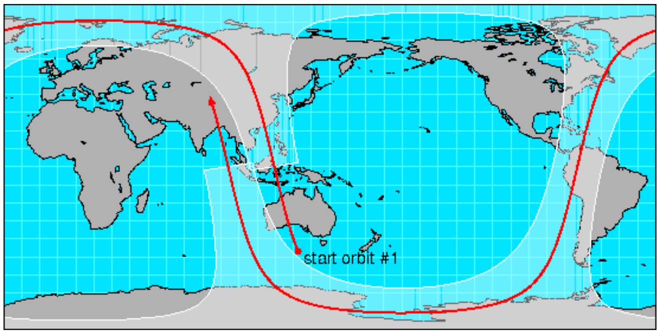
Geostationary satellites orbit in the earth's equatorial plane at a height of 38,500 km. At this height, the satellite's orbital period matches the rotation of the Earth, so the satellite seems to stay stationary over the same point on the equator. Since the field of view of a satellite in geostationary orbit is fixed, it always views the same geographical area, day or night. This is ideal for making regular sequential observations of cloud patterns over a region with visible and infrared radiometers.

Russia has launched a geostationary satellite with meteorological capabilities, but has had difficulty producing useful imagery on a regular basis. In the next year or two, China plans to launch their own geostationary meteorological satellite, named Fengyun-2.

Polar Orbiting Satellites

Polar orbiting satellites are an important class of meteorological and geophysical satellite. Typically, these satellites are placed in circular sun-synchronous orbits. Their altitudes usually range from 700 to 800 km, with orbital periods of 98 to 102 minutes. Satellites in this category include the NOAA Polar-orbiting Operational Environmental Satellites (POES), satellites of the Defense Meteorological Satellite Program (DMSP), Landsat, and SPOT. *These figures illustrate the orbital track for a sun-synchronous satellite in near-polar orbit.*





Note that the orbit is slightly tilted towards the northwest and does not actually go over the poles. While the path (dark line) follows the earth track of the satellite, the lighter grey indicates the coverage area for the AVHRR imaging instrument carried by NOAA/POES satellites. This instrument scans a roughly 3000 km wide swath. The map projection used in this illustration, a cylindrical equidistant projection, becomes increasingly distorted near the poles, as can be seen by the seeming explosion of the viewing area as the satellite nears its northern and southern most orbital limits. For a more realistic view of the satellite orbit in the polar regions, it is better to use a different map projection or a globe.

Analysis:

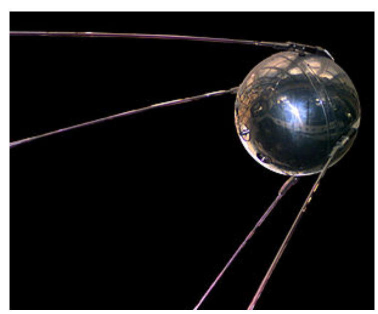
Answer the following questions on lined paper.

1. List the three orbital pathways that a satellite can have and briefly describe each.
2. What is the relationship between altitude and orbital period?
3. What types of equipment is needed on all satellites?
4. How does a satellite remain in orbit?
5. List the six categories of satellites and briefly describe each.
6. Draw a Venn Diagram comparing two of the types of the categories of satellites you listed in the last question.
7. Draw a Venn Diagram comparing the two orbital pathways you learned about in this reading.

The Life and Death of a Satellite

Procedure:
Read through the following passage. **Underline statements** that you feel are important to the tone and message of the article.

History
In 1955, the United State and Soviet Union announced plans to launch artificial satellites. On Oct. 4, 1957, the Soviet Union launched Sputnik 1 *(picture on right)*, the first artificial satellite. It circled Earth every 96 minutes and transmitted radio signals that could be received on Earth. On Nov. 4, 1957, the Soviets launched a second satellite, Sputnik 2. It carried a dog named Lalka, the first animal to soar in space *(shown below)*. The United States launched it's first satellites, Explorer 1, on Jan. 31, 1958, and second on, Vanguard 1, on March 17, 1958.



In August 1960, the United States launched the first communication satellite, Echo 1. This satellite reflected radio signals back to Earth. In April 1960, the first weather satellite, Tiros 1, send pictures of clouds to Earth. The U.S. Navy developed the first navigation satellites. The Transit 1B navigation satellite first orbited Earth in April 1960. By 1965, more than 100 satellites were being placed into orbit each year.

Since the 1970s, scientists have created new and more effective satellite instruments and have made use of computers and miniature electronic technology in satellite design and construction. In addition, more nations and some private businesses have begun to purchase and operate satellites. By 2010, more than 50 countries owned satellites, and nearly 4000 satellites were orbiting Earth!

Building a Satellite

Every satellite carries special instruments that enable it to perform its mission. For example, a satellite that studies the universe has a telescope. A satellite that helps forecast the weather carries cameras to track the movement of clouds.

In addition to such mission specific instruments, all satellites have basic subsystems, groups of devices that helps the instruments work together and keep the satellite operating. For example, a power subsystem generates, stores, and distributes a satellite's electric power. This subsystem may include panels of solar cells that gather energy from the sun. Command and data handling subsystems consist of computers that gather and process data from the instruments and execute commands from Earth.
A satellite's instruments and subsystems are designed, built, and tested individually. Workers install them on the satellites one at a time until the satellite is complete. Then the satellites is tested under conditions like those that the satellite will encounter during launch and while in space. If the satellite passes all tests, it is ready to be launched.

Launching the Satellite

Space shuttles carry some satellites into space, but most satellites are launched by rockets that fall into the ocean after their fuel is spent. Many satellites require minor adjustments of their orbit before they begin to perform their function. Built-in rockets called thrusters make these adjustments. Once a satellite is placed into a stable orbit, it can remain there for a long time without further adjustment.

Performing the Mission

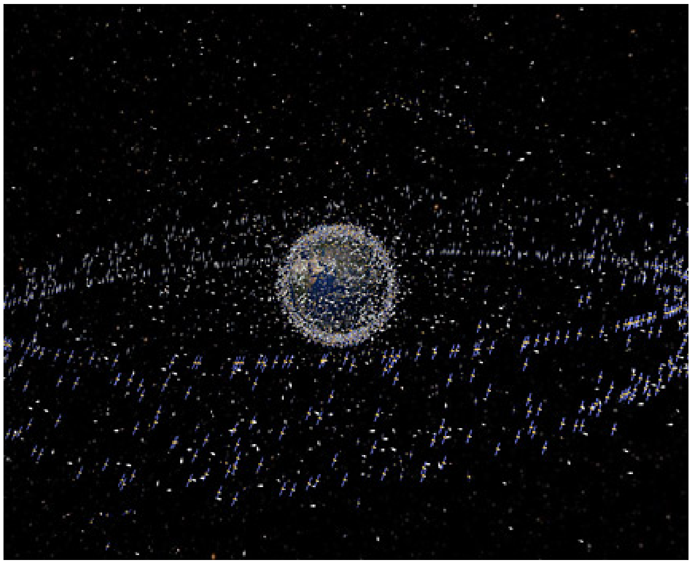
Most satellite operations are directed from a control center on Earth. Computers and human operators at the control center monitor the satellite's position, send instructions to computers, and retrieve information hat the satellite has gathered. The control center communicates with the satellite by radio. Ground stations within the satellite's range send and receive radio signals.

A satellite does not usually receive constant direction from its control center. It is like and orbiting robot. It controls it solar panels to keep them pointed toward the sun and keeps its antennas ready to receive commands. Its instruments automatically collect information.

Satellites in a high altitude, geosynchronous orbit are always in contact with Earth. Ground stations can contact satellites in low orbits as often as 12 times a day. During each contact, the satellite transmits information and receives instructions. Each contact must be completed during the time the satellite passes over head – about 10 minutes.

If some part of a satellite breaks down, but the satellite remains capable of being used, the satellite owner usually will continue to operate. In some cases, ground controllers can repair or reprogram the satellite from Earth. In rare instances, space shuttle crews have retrieved and repaired satellites in space.

Falling from Orbit



A satellite must remain in orbit until its velocity decreases and the gravitational force pulls it down into a relatively dense part of the atmosphere. A satellite slows down due to occasional impact with air molecules in the upper atmosphere and the gentle pressure of the sun's energy. When the gravitational force pulls the satellite down far enough into the atmosphere, the satellite rapidly compresses the air in front of it. The air becomes so hot that most or all of the satellite burns up.

With more than two satellites per week being put up into space, that sure is a lot of junk in space. On the picture to the left, each light dot represents a man-made satellite.

Analysis:

Answer the following questions on lined paper.

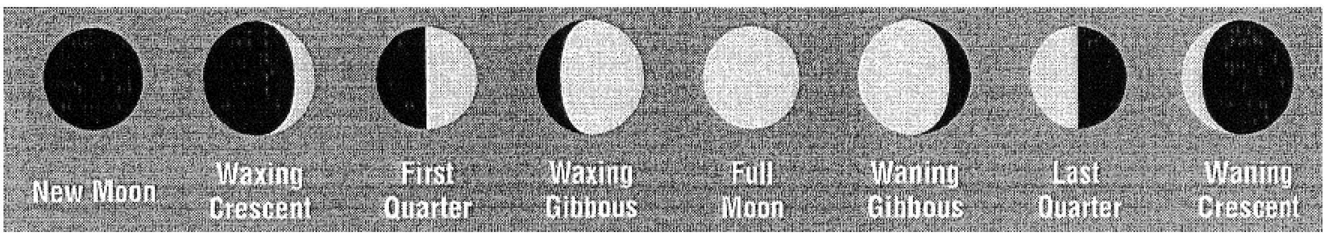
8. How did man-made satellites get their start?
9. How are satellites tested?
10. How have satellites been upgraded in more recent times?
11. How does a satellite come back to Earth?
12. Should we "police" what is sent into space? Why/ why not?
13. What did you find most interesting about this reading? Why so?
14. What would you like to still know about man-made satellites?

Lunar Phases

Every 29.52 days the Moon goes through a predictable cycle of changes in its shape which we call phases. For thousands of years, people have recorded these phases and during this time, the. cycle has never changed. Even though it is known with great accuracy what the Moon will look like on any night of the year, many people cannot explain why the Moon's shape appears to change. Some people say that the Earth's shadow falls on the Moon and blocks our view of it. Others say that clouds block part of the Moon. Both explanations are incorrect.

Actually, the physical shape of the Moon never changes. It is always a sphere with millions of craters and other landforms on it. What changes is the portion of the Moon that can be seen from Earth/ Half of the Moon is always illuminated by the Sun. It has no light of its own but shines by sunlight reflected from its surface. Sometimes the entire illuminated part of the Moon can be seen from Earth; this is called a Full Moon. At other times, none of the illuminated part can be seen; a New Moon. And all the stages in between a New and Full Moon occur as well. But why does the shape of the Moon appear to change in this way? It is because the Moon is in orbit around Earth.

The Moon takes about 29.5 days to orbit the Earth and make a complete cycle (Lunar Cycle) through its phases. The Moon doesn't actually change shape during each phase, we just see different amounts of sunlight reflected off of the Moon's surface. The phases are the changes in the different amounts of lighted surface of the Moon that we can see from Earth. During the New Moon phase, the Moon is between the Earth and the Sun. The side of the Moon that is not lit is facing the Earth, so we don't see the Moon during that phase.



During its 29.5 day revolution around the Earth, the Earth rotates 29.5 times. This is why the same side of the moon always faces Earth. Similarly, because there are 30 or 31 days in most months, having two Full Moons in one month only occurs once every three years or so. When two Full Moons occur in the same calendar month, we refer to it as a Blue Moon. Hence the phrase "Once in a Blue Moon."

In order to understand the phases of the Moon, we should note that the Moon undergoes a few important phenomena;

1. the Moon has a cycle of phases that lasts 29.5 days
2. the Moon appears to move across the night sky because of the Earth's rotation
3. the Moon "rises" and "sets" at different times during the course of a lunar month (29.5 days) because of it's orbit around the Earth
4. After the New Moon, the Moon becomes more illuminated from right to left as it passes through it's phases.

(Ping Pong and Globe demo of phases).

Question: What are the phases of the Moon and what causes them?

Background: *(write a few things that you already know pertaining to about the question above)*
Vocabulary:
Gibbous
Waning
Waxing
Crescent
New Moon
Full Moon

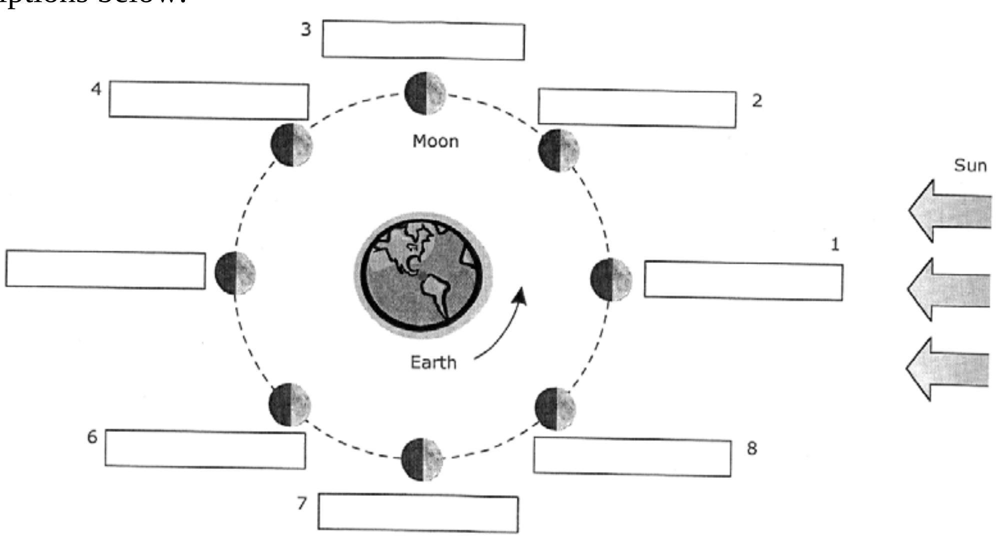
Materials:
Ping Pong Ball
Globe
Light source
This assignment sheet

Procedure:
Answer the questions as you go continue through the assignment.

Part 1 - Defining the phases

Wax, wane, crescent, gibbous, quarter, full, revolve, rotate, lunar ... are words you need to know if you're going to speak moon. These describe the movements and phases of the moon.

Write the correct phase or position of the moon in the diagram. Then write the name with the proper descriptions below.



___________________ 9. "The moon lies between the sun and Earth so the. side of the moon facing Earth is dark and the moon is not visible."

___________________ 10. "More than a quarter of the moon is visible, and the visible portion is becoming smaller as the moon moves toward the third quarter phase."

__________________ 11. "The moon has moved eastward in its orbit from the new moon phase and forms a 90° angle with the sun and Earth, and the moon appears half bright and half dark."

__________________ 12. "Although less than a quarter of the moon is visible now, the visible portion is getting larger as the moon moves from the new moon phase toward the first quarter phase."

__________________ 13. "The moon is aligned with the sun and Earth, Earth being in the middle. The entire side of the moon facing Earth is bright and visible."

__________________ 14. "Less than a quarter of the moon is visible, and the visible part is getting even smaller as the moon moves toward the new moon phase."

__________________ 15. "The moon is moving toward the full moon phase, and presently more than a quarter of it is visible on Earth."

__________________ 16. "The moon, sun, and Earth are forming a 90° angle, so the side of the moon facing Earth is half dark and half bright. The visible part of the moon will be getting smaller as it moves toward the new moon phase."

Part 2 - The Lunar Calendar

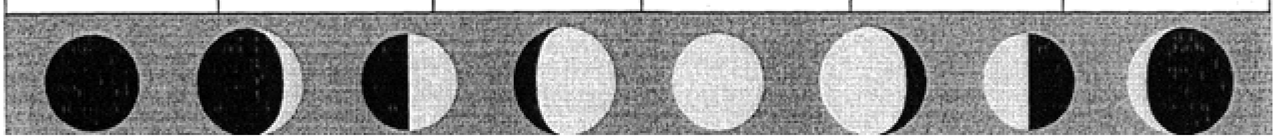
It is easy to see the changes in the appearance of the Moon, so early peoples frequently based their calendars on the cycles of the Moon. The word "month" come from the same word as "moon." However, the months of our solar calendar are no longer lunar months.

Since the Moon takes 29.5 days to complete a cycle of lunar phases, 12 lunar months is 11 days short of a solar years (365.25 days). In spite of this difference, many people still organize their lives by lunar calendars. Two of the World's great religions, Judaism and Islam keep lunar calendars. This is why the holy month of Ramadan, a time of prayer and fasting among Muslims, continually moves through the seasons, occurring 11 days earlier each year.

The Jewish calendar has 12 or 13 months lunar months. The standard year is 12 months, but an extra month is inserted seven times during a 19-year cycle to keep the religious calendar closely aligned with the solar calendar. Thus, Jewish holidays always occur in the same season, but not on the same date.

Find the date of the full moon for this month. Use that as your starting point to fill in the occurrence of each of the eight phases of the moon for this month in the calendar below. Draw what the phase would look like and include the name of that phase.

1	2	3	4	5	6
7	8	9	10	11	12
13	14	15	16	17	18
19	20	21	22	23	24
25	26	27	28	29	30



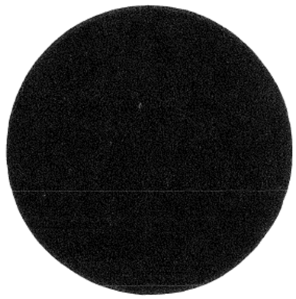
Analysis:

Answer the following questions on lined paper.

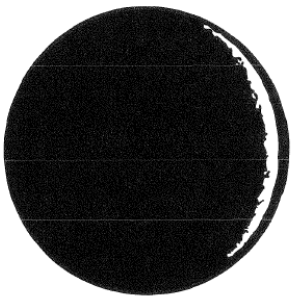
1. What causes the phases of the Moon?
2. How long does it take the Moon to go through its phases?
3. Starting at New Moon, what are the phases of the Moon in order?
4. Draw a Venn Diagram comparing the terms waxing and waning.
5. Draw a Venn Diagram comparing the terms gibbous and crescent.
6. How is it that we only see the same side of the Moon?
7. Why do some people refer to the back side of the Moon as the "dark side"? Are they correct? Why so?
8. Why is it possible to see one of the crescent phases during the daylight hours but not one of the gibbous phases?
9. Why is not possible to see the New Moon Phase at night? (Please put in terms of location of the Sun, not illumination of the Moon)
10. What is meant by a "Blue Moon"?
11. How many days are in a lunar "year" of 12 lunar months? How many days are in a solar year?
12. Not counting leap years, how many days are in 19 solar years?
13. How many days are there in 19 lunar calendar years with an extra month added in seven times?
14. After a period of 19 years, how closely does the Jewish calendar coincide with the solar calendar?

The Lunar Phases

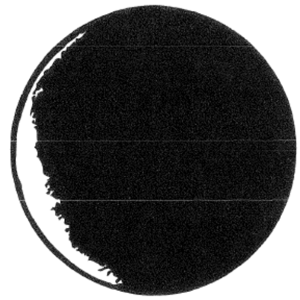
New moon occurs when the lighted side of the moon is facing away from Earth. The next new moon will occur about 29½ days after this one.

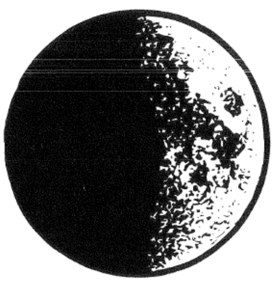


This waxing crescent occurs about three days after new moon. All the phases between new moon and first quarter are called waxing crescent.



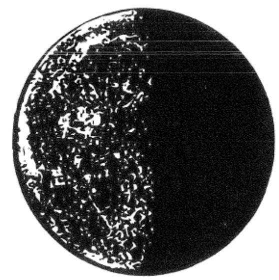
This waning crescent occurs about 25 days after new moon. All the phases between third quarter and new moon are called waning crescent.

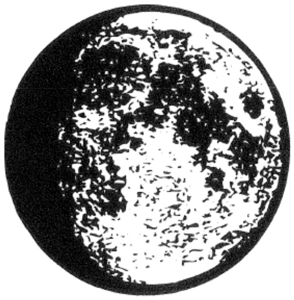




First quarter moon occurs approximately seven days after new moon, when exactly ¼ of the moon is visible to viewers on the Earth.

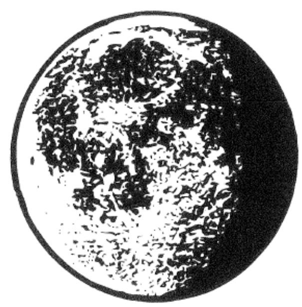
Third quarter occurs about 22 days after new moon when exactly ¼ of the moon is visible to viewers on the Earth.





This waxing gibbous occurs about 11 days after new moon. All the phases between first quarter and full moon are called waxing gibbous.

Full moon occurs a little over 14 days after new moon when the lighted side of the moon is facing toward Earth.



This waning gibbous occurs 17 days after new moon. All the phases between full moon and third quarter are called waning gibbous.

LaBella Luna

Introduction:
The Moon or "Luna," orbits Earth from West to East-a "counterclockwise" direction. It reflects light from the Sun and is considered Earth's only natural satellite. During the course of one month on Earth (27.52 Earth days), we view the Moon as it orbits Earth in its elliptical orbit (Earth is located at one of the two foci). The lunar surface facing the Sun is always illuminated.

Since Earthlings don't always see this entire illuminated side, humans have come to label the portions of the illuminated side visible while on Earth. These are called the Lunar Phases. Remember that Earth continues to revolve in its orbit around Sol at the same time that Luna revolves around Earth.

Question: What are the phases of the Moon and what causes them?

Background: *(write a few things that you already know pertaining to about the question above)*

Vocabulary:
Lunar Phase
Waxing
Waning
Crescent
Gibbous
Quarter
New Moon
Full Moon
Top View
Profile View

Materials:
This handout

Procedure:
While you read through the following sections, follow the instructions and answer the questions as you come across them.

Part 1 - Plotting lunar cycle coordinates
1. Use the Lunar Coordinates Data Table below to plot the Lunar longitude at the appropriate location on the Lunar Orbit Graph (see example for July 1st on the graph).

2. Place each dot on the bolded ellipse shown on the graph.

Lunar Coordinates Data Table - The values on the following table correspond to celestial longitude values found on the Radial Graph paper.

July Date	Lunar Longitude C)	Solar Longitude C)
1	115	99
3	145	101
5	175	103
7	205	105
9	235	107
11	265	109
13	295	111
15	325	113
17	355	115
19	25	117
21	55	119
23	85	121
25	100	123
27	130	125
29	165	127
31	195	129

3. On the Lunar Orbit Graph, label each of the lunar positions with the appropriate July date.

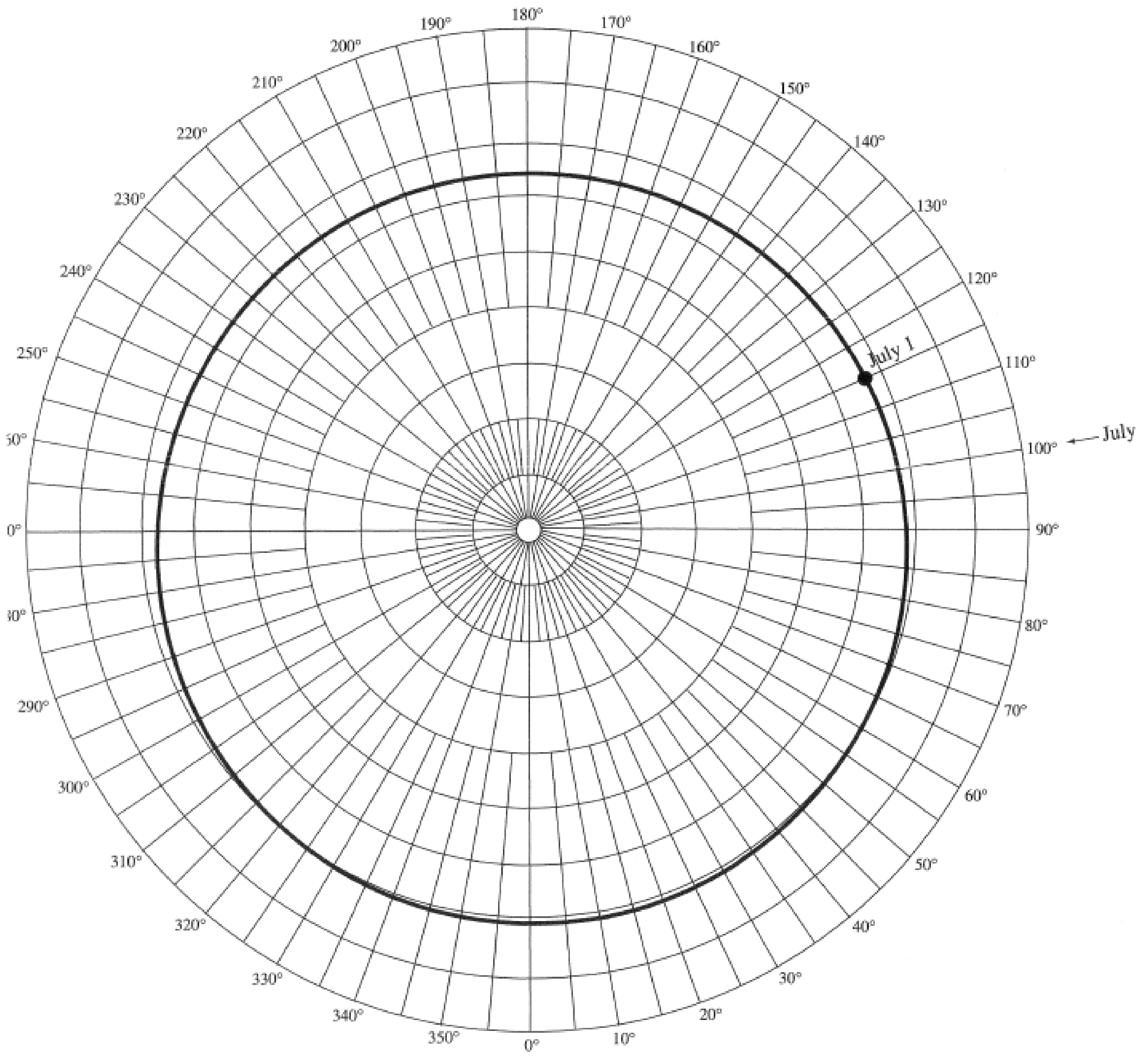
4. Draw arrows on this ellipse showing the direction of motion of the Moon around Earth.

5. Draw the astronomical symbol for Earth at the center of the radial graph paper.

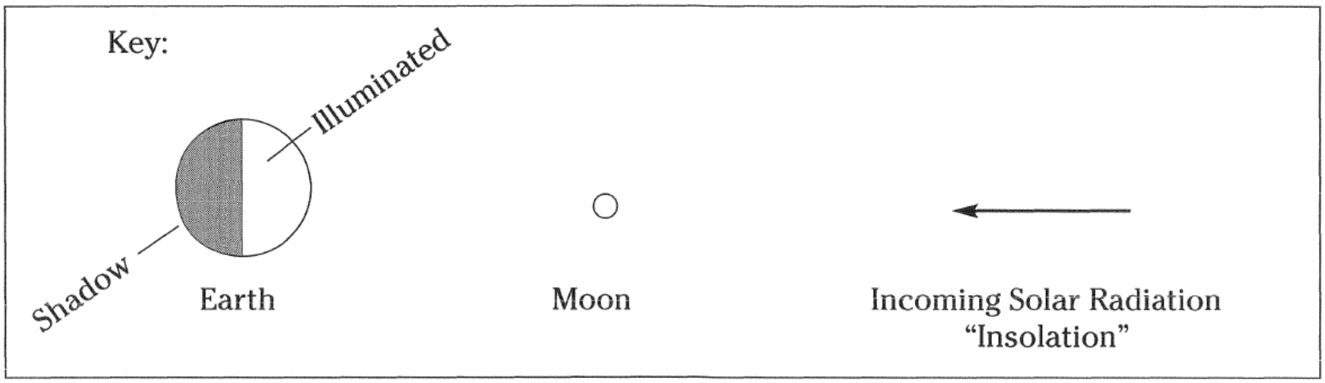
6. Draw an arrow representing the direction of Solar Longitude for each of the solar longitude degrees listed on the Lunar Coordinates Data Table. This is the direction of Incoming Solar Radiation each day in July. Place the arrow outside the radial graph pointing toward Earth (notice that the arrow for July 1st has already been completed).

7. Label each Insolation arrow with the appropriate date.

Lunar Orbit Graph

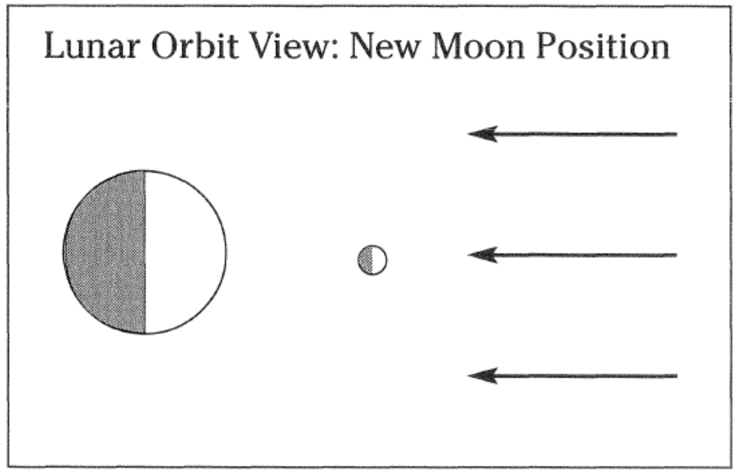


Part 2 - Locating and Drawing Each Lunar Phase



A. The New Moon

• Locate the July 1st position of the New Moon between Sol (Insolation arrows for July) and Earth on the Lunar Orbit Graph. See the example at right.

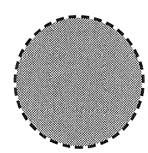


• Enlarge this dot to a 1.0 cm diameter circle (this will represent the position of the New Moon in its orbit).

• Shade in the portion of this circle (with a pencil) that would not receive sunlight on its surface in the Lunar Orbit. Incoming Solar Radiation "Insolation"

Positions on the Lunar Orbit Graph do not currently show lunar phases. Lunar phases are dependent upon the observer seeing the Moon from Earth. Since you, the observer, are viewing the relative positions of the Earth, Moon and Sol from a position "above" them, by definition you are not actually viewing the illuminated portions of the Moon's surface from Earth. In this activity, the Phases will be drawn on the Lunar Phase Diagrams as seen from the Earth's surface.

• Turn the Lunar Orbit Graph so that the position of the New Moon from the viewpoint of Earth is seen (remember, the Earth is in the center of the graph). An observer on Earth would only see the side of Luna that is not receiving illumination from Sol. To represent this entire unlit portion of the Moon facing Earth, shade in the dashed-line circle shown on the Lunar Phase Diagrams (see sample at right).

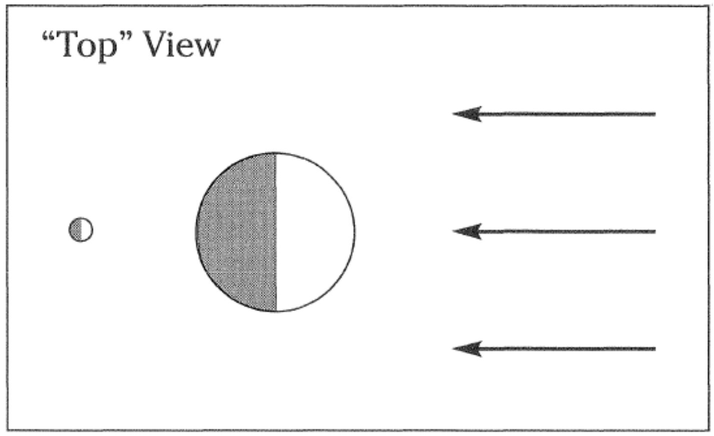


• Label this the "New Moon Phase."

WARNING! Remember that Sol will change position relative to both Earth and Moon. Be certain that all three celestial objects are located in a straight line of your Incoming Solar Radiation.

B. The Full Moon

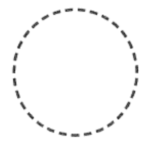
• Locate the dot where the July position of the Full Moon is in line with Sol (Insolation arrows) and Earth on the Lunar Orbit Graph. See the example at right.



• Enlarge the dot to a 1.0 cm diameter circle (this will represent the position of the Full Moon in its orbit).

• Shade in the portion of this circle (with a pencil) that would not receive sunlight on its surface in the Lunar Orbit.

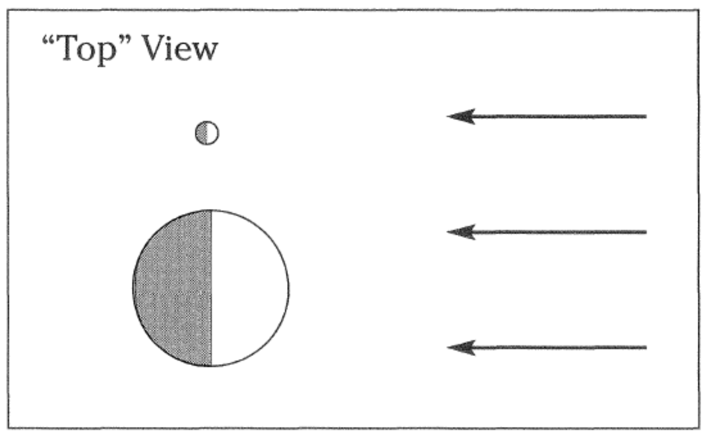
• Turn the Lunar Orbit Graph so that the position of your Full Moon from the viewpoint of Earth is seen. An observer on Earth would see the entire illuminated half of the Moon. To represent the entire portion of the Moon facing Earth at this position, do not shade in any portion of the circle shown on the Lunar Phase diagram.



• Label this the "Full Moon Phase" on the line provided next to the Lunar Phase Diagram.

C. The First Quarter Phase

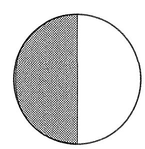
• Locate the dot where the July position of the First Quarter Moon is situated at a right angle from the Earth and Sun on the Lunar Orbit Graph. See the example at right.



• Enlarge the dot to a 1.0 cm diameter circle (this will represent the position of the First Quarter Moon in its orbit).

• Shade in the portion of this circle (with a pencil) that would not receive sunlight on its surface in the Lunar Orbit.

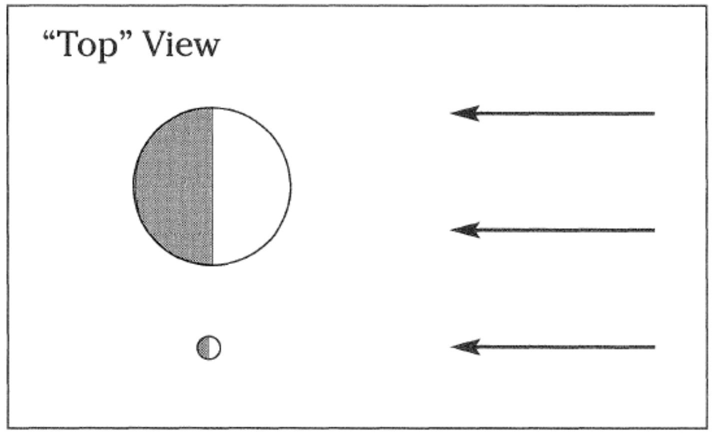
• Turn the Lunar Orbit Graph so that the position of your First Quarter Moon from the viewpoint of Earth is seen. An observer on Earth would see only the right half of the Moon's surface illu- minated. To represent the entire portion of the Moon facing Earth at this position, shade in the left half of the circle shown on the Lunar Phase Diagram.



• Label this the "First Quarter Phase" on the line provided next to the Lunar Phase Diagram.

D. The Third Quarter Phase

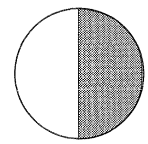
• Locate the dot where the July position of the Third Quarter Moon is situated at a right angle from the Earth and Sun. See the example at right.



• Enlarge the dot to a 1.0 em diameter cir- cle (this will represent the position of the Third Quarter Moon in its orbit.

• Shade in the portion of this circle (with a pencil) that would not receive sunlight on its surface in the Lunar Orbit.

• Turn the Lunar Orbit Graph so that the position of the Third Quarter Moon from the viewpoint of Earth is seen. An observer on Earth would see only the left half of the Moon's surface illuminated. To represent the entire portion of the Moon facing Earth at this position, shade in the right half of the circle shown in the Lunar Phase Diagram.



• Label this the "Third Quarter Phase" on the line provided next to the Lunar Phase Diagram.

E. Waxing and Waning Trends in Lunar Phases

As the Moon revolves around Earth in a counterclockwise direction (from West to East), there is a period of about two weeks (13-15 days) where Earthlings see illuminated portions of the lunar surface increasing each night. Then, for another period of about two weeks (13-15 days), Earthlings view the amounts of illuminated surface of the moon diminishing each night. These trends in the phases are called "waxing" and "waning." Lunar phases are considered "waxing" between the New Moon and Full Moon positions. Each phases has a lit- tle more of the illuminated half of the Moon that is visible from Earth. Lunar phases are con- sidered "waning" if they are located between the Full and New Moon phases. Each phase dis- plays a little less of the illuminated half of the Moon visible from Earth each night.

F. Locating the Waxing Phases

•Draw a dot on the Lunar Orbit Graph halfway between the New Moon and the First Quarter Phase. (Calculate the Lunar longitude of this point by using the Lunar Coordinates Table.)

•Enlarge the dot to a 1.0 cm diameter circle.

•Label this position "Waxing ...." on the Lunar Phase Diagram. (The second word will be filled in later.)

•Draw a dot on the Lunar Orbit Graph halfway between the First Quarter Moon and the Full Moon Phase. (Calculate the Lunar longitude of this point by using the Lunar Coordinates Table.)

•Enlarge the dot to a 1.0 cm diameter circle.

•Label this position "Waxing ...." on the Lunar Phase Diagram. (The second word will be filled in later.)

G. Locating the Waning Phases

- Draw a dot on the Lunar Orbit Graph halfway between the Full Moon and the Third Quarter Phase. (Calculate the Lunar longitude of this point by using the Lunar Coordinates provided in the Lunar Coordinates Table.)

- Enlarge the dot to a 1.0 cm diameter circle.

- Label this position "Waning ...." on the Lunar Phase Diagram. (The second word will be filled in later).

- Draw a dot on the Lunar Orbit Graph halfway between the Third Quarter Moon and the New Moon Phase. (Calculate the Lunar longitude of this point by using the Lunar Coordinates provided in the Lunar Coordinates Table.)

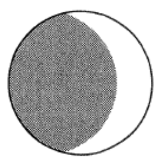
- Enlarge the dot to a 1.0 cm diameter circle.

- Label this position "Waning ...." on the Lunar Phase Diagram. (The second word will be filled in later.)

H. Locating the Crescent Phases

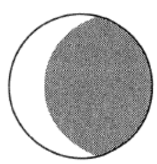
Luna appears in a crescent phase while in orbit on either side of the New Moon position. A Crescent Phase is when the Moon is in orbit halfway between a Quarter phase and the New Moon phase. Whether or not the amount of illumination we see from Earth is increasing or decreasing, a crescent phase will have another term attached: "waxing" or "waning."

- Draw the Waxing Crescent Phase on the Lunar Phase Diagram.



- Complete the label for this phase on the Lunar Phase Diagram so that it reads "Waxing Crescent" Phase.

- Draw the Waning Crescent Phase on the Lunar Phase Diagram.



- Complete the label for this phase on the Lunar Phase Diagram so that it reads "Waning Crescent" Phase.

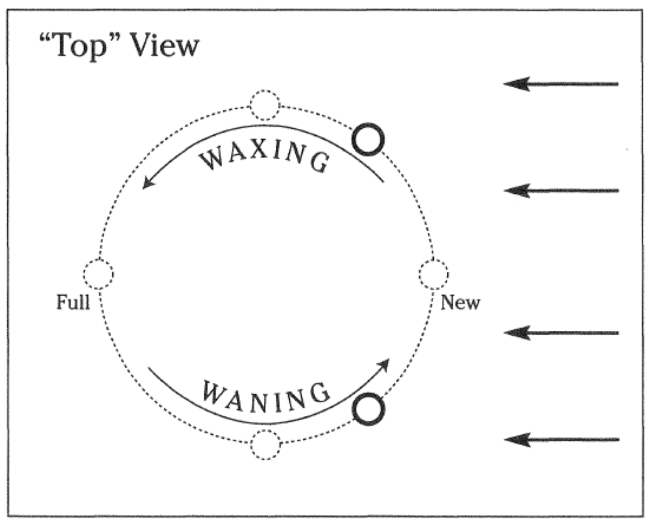


Figure A.

I. Locating the Gibbous Phases

Luna appears in a gibbous phase while in orbit on either side of the Full Moon position. A Gibbous Phase is when the Moon is in orbit halfway between a Quarter phase and the Full Moon phase. Whether or not the amount of illumination we see from Earth is increasing or decreasing, a gibbous phase will have another term attached: "waxing" or "waning."

•Draw the Waxing Gibbous Phase on the appropriate Lunar Phase Diagram.

•Complete the label for this phase on the Lunar Phase Diagram so that it reads "Waxing Gibbous" Phase.

•Draw the Waning Gibbous Phase on the appropriate Lunar Phase Diagram.

•Complete the label for this phase on the Lunar Phase Diagram so that it reads "Waning Gibbous" Phase.

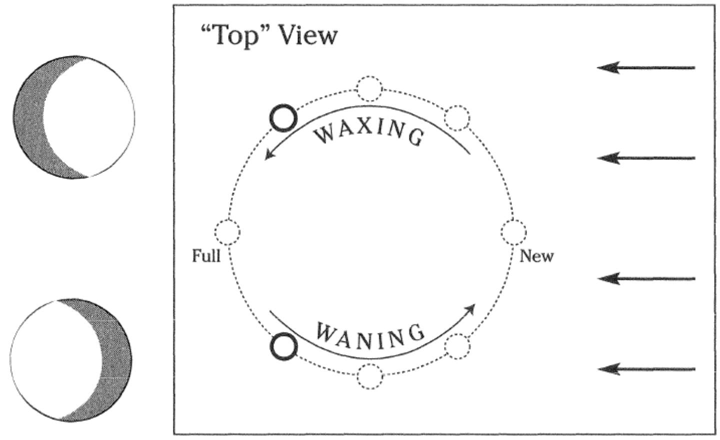


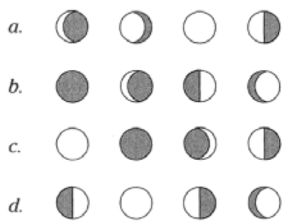
Figure B.

Analysis:

Answer the following questions on lined paper in complete sentences which restate the question in your answer when applicable.

Sol appears to move approximately 30° each month as Earth revolves counterclock-wise in orbit (there are 365.25 days in the year, our orbit has 360°). Draw a circle on the Lunar Orbit Graph just outside the lunar orbit at the position of the next Full Moon. Label it "NEXT Full Moon."

1. What is the approximate date of this next Full Moon phase?
2. How does the lunar orbit compare to a circular path (put this in terms of eccentricity)?
3. Which of the following show the correct order of phases for one orbit?



Draw figure C on your sheet and use it to answer the following questions.

4. Label each lunar phase name below for the positions shown in the diagram.
5. On Figure C, shade in the appropriate portion of each circle to represent the appearance of Luna as it would appear to an observer on Earth.
6. On Figure C, draw an arrow between each lunar position showing the direction of revolution.
7. Since half of Luna is always illuminated by Sol, why do we not see the Full Moon phase all month long?
8. What is the only event that Luna is not struck by solar rays?
9. Explain why a lunar eclipse is not seen every month.

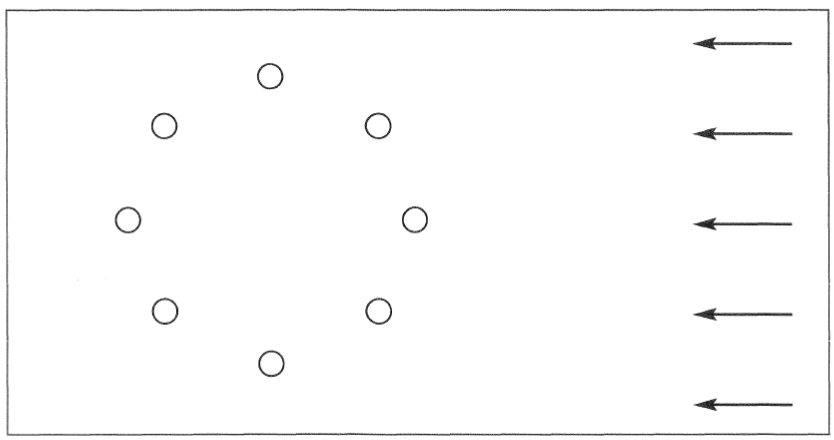
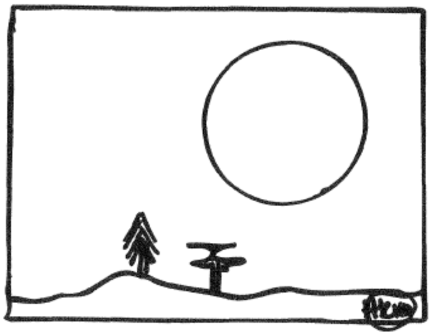


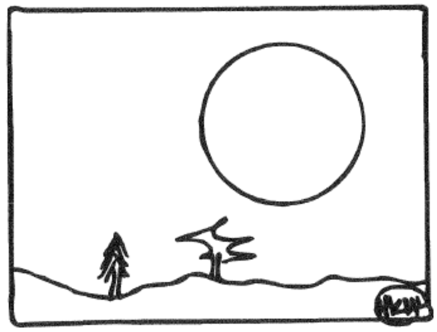
Figure C.

10. What phase position would the Moon have to be in for us to see a lunar eclipse?
11. Place an "X" on this position in Figure C above.
12. What phase position would the Moon have to be in for us to see a solar eclipse?
13. Place a "*" on this position in Figure C above.
14. In all diagrams shown (except the Lunar Orbit Graph) the lunar orbit appears to be a perfect circle. Why do you think this is so?
15. Describe the eccentricity of the lunar orbit (i.e., It appears to be circular).
16. What period of time is represented by one period of revolution of the Moon around
17. Earth?
18. How many days does this average out to be?
19. How many days does it take for the Moon to move from the New Moon to the Full Moon position?
20. How many days does it take for the Moon to move from the Third Quarter to the New Moon position?
21. How many days does it take for the Moon to move from the First Quarter to the Third Quarter position?

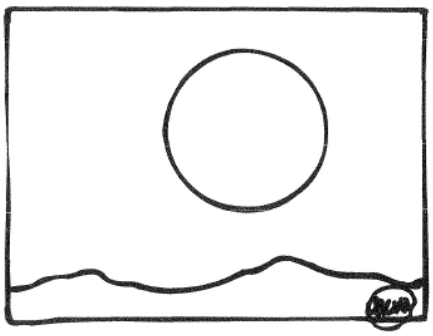
Lunar Phase Diagrams



~ 210°

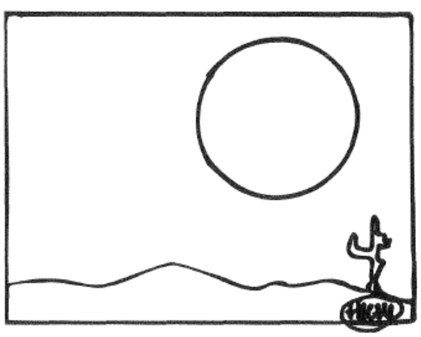


~ 160°

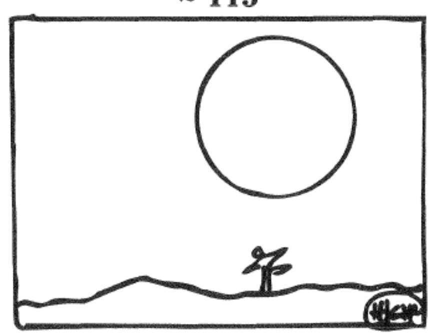


~ 240°

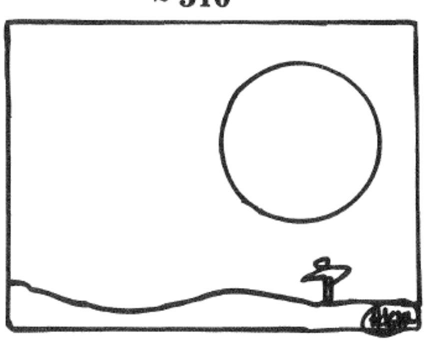
~ 115°



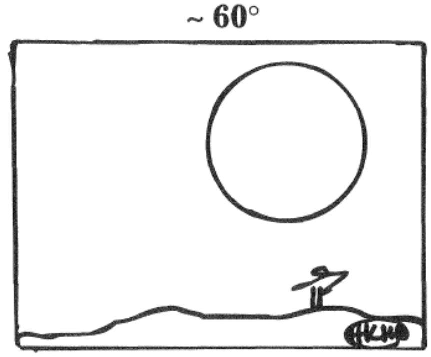
~ 310°



~ 60°



~ 340°



~ 20°

Solar and Lunar Eclipses Reading

Introduction:
In order to understand eclipses, we need to first talk about the Moon. The Moon is a cold, rocky body about 2,160 miles (3,476 km) in diameter. It has no light of its own but shines by sunlight reflected from its surface. The Moon orbits Earth about once every 29.5 days. As the Moon orbits Earth, the changing position of the Moon with respect to the Sun causes our natural satellite to cycle through its series of phases.

When the Moon is New, it rises and sets with the Sun because it lies very close to the Sun in the sky. Although we cannot see the Moon during *New Moon* phase, it has a very special significance with regard to eclipses.

Phases of the Moon.

An eclipse of the Sun (or solar eclipse) can *only* occur at New Moon when the Moon passes between Earth and Sun. If the Moon's shadow happens to fall upon Earth's surface at that time, we see some portion of the Sun's disk covered or 'eclipsed' by the Moon. Since New Moon occurs every 29.5 days, you might think that we should have a solar eclipse about once a month. Unfortunately, this doesn't happen because the Moon's orbit around Earth is tilted 5 degrees to Earth's orbit around the Sun. As a result, the Moon's shadow usually misses Earth as it passes above or below our planet at New Moon. At least twice a year, the geometry lines up just right so that some part of the Moon's shadow falls on Earth's surface and an eclipse of the Sun is seen from that specific region.

Question: What are the types of eclipses and what causes each?

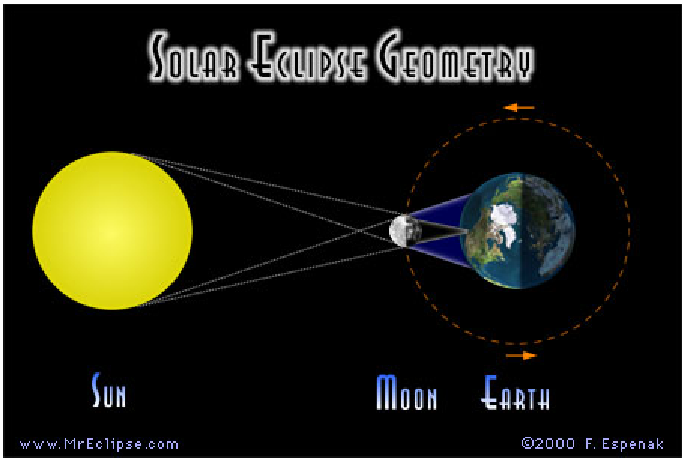
Background: *(write a few things that you already know pertaining to about the question above)*

Vocabulary:
Penumbra
Umbra
Path of Totality
Total Solar Eclipse
Partial Solar Eclipse
Annular solar eclipse
Penumbral lunar eclipse
Partial lunar eclipse
Total lunar eclipse

Materials:
This reading packet

Procedure:
Read through the following passage.

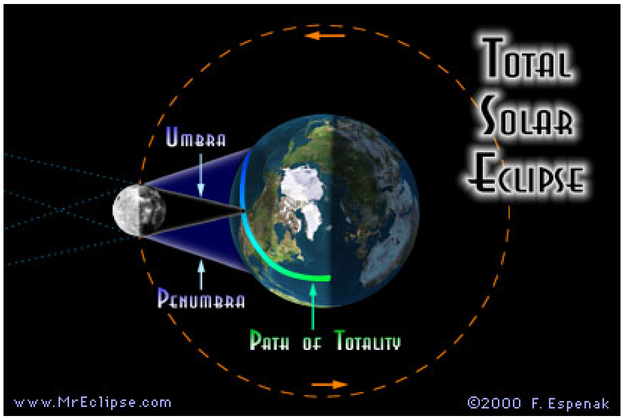
The Anatomy of a Solar Eclipse
The Moon's shadow actually has two parts:
Penumbra - Faint outer shadow; partial eclipses are seen from within this shadow.
Umbra- Dark inner shadow; total eclipses are seen from within this shadow.

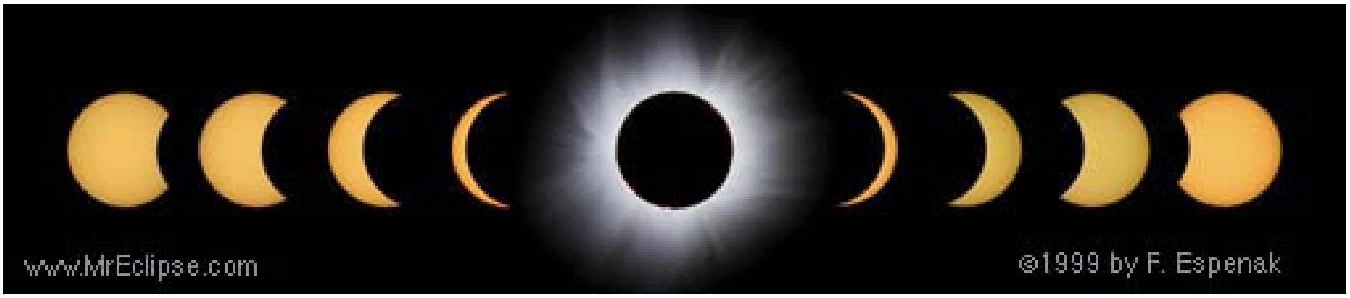


When only the Moon's penumbral shadow strikes Earth, we see a partial eclipse of the Sun from that region. Partial eclipses are dangerous to look at because the un-eclipsed part of the Sun is still very bright. You must use special filters or a home-made pinhole projector to safely watch a partial eclipse of the Sun.

However, if the Moon's dark umbral shadow sweeps across Earth's surface, then a total eclipse of the Sun is seen (see figure below). The track of the Moon's shadow across Earth's surface is called the Path of Totality. It is typically 10,000 miles long but only 167 miles or so wide. In order to see the Sun totally eclipsed by the Moon, you must be in the path of totality.

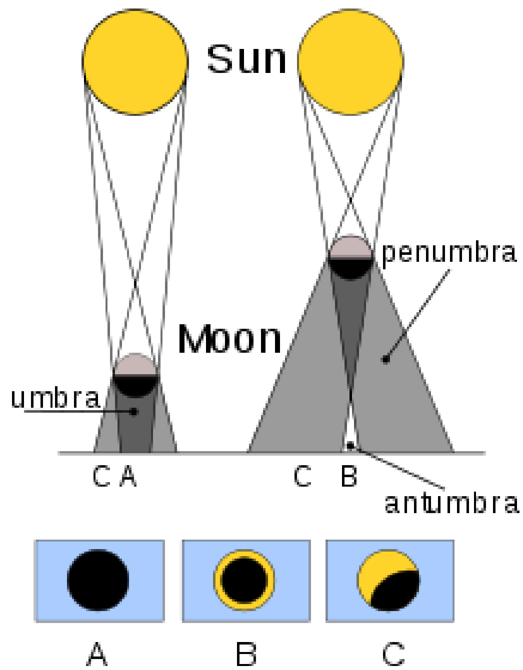
Total Solar Eclipse and the Path of Totality
The total phase of a solar eclipse is very brief. It rarely lasts more than several minutes. Nevertheless, it is considered to be one of the most awe inspiring spectacles in all of nature. The sky takes on an eerie twilight as the Sun's bright face is replaced by the black disk of the Moon. Surrounding the Moon is a beautiful halo. This is the Sun's spectacular solar corona, a super heated plasma two million degrees in temperature. The corona can only be seen during the few brief minutes of totality. In fact, the maximum time for a total solar eclipse is 7 minutes and 40 seconds. This occurs because the eclipse shadow moves at 2,000 mph at the Earth's poles and 1,000 mph at the Earth's equator.





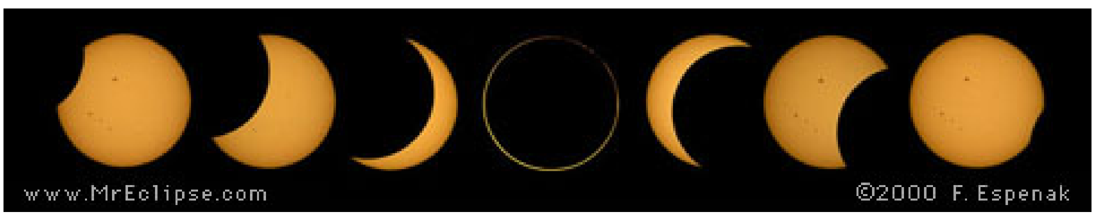
Eclipse sequence

Annular Solar Eclipse and the Path of Annularity



Unfortunately, not every eclipse of the Sun is a total eclipse. Sometimes, the Moon is too small to cover the entire Sun's disk. To understand why, we need to talk about the Moon's orbit around Earth. That orbit is slightly elliptical in shape. As the Moon orbits our planet, it's distance varies from 221,000 to 252,000 miles. This 13% variation in the Moon's distance makes the Moon's apparent size in our sky vary by the same amount. When the Moon is on the near side of its orbit, the Moon appears larger than the Sun. If an eclipse occurs at that time, it will be a total eclipse. However, if an eclipse occurs while the Moon is on the far side of its orbit, the Moon appears smaller than the Sun and can't completely cover it. This is called an annular eclipse.

Since the annular phase is so bright, the Sun's gorgeous corona remains hidden from view. But just like total solar eclipses, annular eclipses are still quite brief and interesting to watch. The maximum time for an annular solar eclipse is 12 minutes 24 seconds.



Annular eclipse sequence- this seven image sequence covers an entire 2.5 hour long annular eclipse.

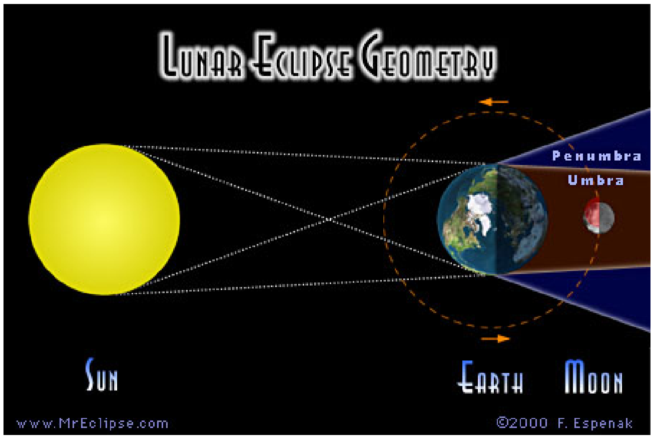
The last total solar eclipse visible from the continental *United States* occurred on Feb. 26, 1979. A total solar eclipse was visible from Hawaii and Mexico on July 11, 1991. The next two total solar eclipses visible from the *United States* occur on Aug. 21, 2017 and Apr. 8, 2024.

If you don't feel like traveling, just wait. At any geographic position on the Earth, a total solar eclipse occur an average of once every 360 years.

For additional information, NASA has a really good solar eclipse website that can be found at http://eclipse.gsfc.nasa.gov/solar.html

Lunar Eclipses

To many of us, *Full Moon* is the phase of love and romance. When the Moon is Full, it rises at sunset and is visible all night long. At the end of the night, the Full Moon sets just as the Sun rises. None of the Moon's other phases have this unique characteristic. It happens because the Moon is directly opposite the Sun in the sky when the Moon is Full. Full Moon also has special significance with regard to lunar eclipses.



An eclipse of the Moon (or lunar eclipse) can *only* occur at Full Moon, and only if the Moon passes through some portion of the Earth's shadow. The shadow is actually composed of two cone-shaped components, one nested inside the other. The outer or penumbral shadow is a zone where the Earth blocks part but not all of the Sun's rays from reaching the Moon. In contrast, the inner or umbral shadow is a region where the Earth blocks *all* direct sunlight from reaching the Moon.

Geometry of the Sun, Earth and Moon During an Eclipse of the Moon. Earth's two shadows are the penumbra and the umbra. (Sizes and distances not to scale)

In theory, if the Moon orbits Earth every 29.5 days and lunar eclipses only occur at Full Moon, then we should have lunar eclipses every month. That would be the case except that the Moon's orbit around Earth is actually tipped about 5 degrees to Earth's orbit around the Sun. This means that the Moon spends most of the time either above or below the plane of Earth's orbit. During a typical Full Moon, the Moon passes just above or below Earth's shadows and no eclipse takes place. But two to four times each year, the Moon passes through some portion of the Earth's penumbral or umbral shadows and one of the above three types of eclipses occurs.

When an eclipse of the Moon takes place, everyone on the night side of Earth can see it. About 35% of all eclipses are of the penumbral type in which the Moon passes through Earth's penumbral shadow. These events are studied only by astronomers and are subtle and quite difficult to detect, even with a telescope. Another 30% are partial eclipses in which a portion of the Moon passes through Earth's umbral shadow. Partial lunar eclipses are easy to see with the unaided eye. The final 35% or so are total eclipses during which the entire Moon passes through Earth's umbral shadow.

Why Lunar Eclipses are Red

Total Lunar eclipses are quite extraordinary events to behold as the Moon turns a rusty red color. During a total lunar eclipse, an astronaut on the Moon would then see the Earth eclipsing the Sun. They would see a bright red ring around the Earth as they watched all the sunrises and sunsets happening simultaneously around the world! Indirect sunlight still manages to reach the Moon and illuminate it. However, this sunlight must first pass deep through the Earth's atmosphere which filters out most of the blue colored light. The remaining light is a deep red or orange in color and is much dimmer than pure white sunlight. Earth's atmosphere also bends or refracts some of this light so that a small fraction of it can reach and illuminate the Moon.

Observing Lunar Eclipses

Unlike solar eclipses, lunar eclipses are completely safe to watch. You don't need any kind of protective filters. It isn't even necessary to use a telescope. You can watch the lunar eclipse with nothing more than your own two eyes. If you have a pair of binoculars, they will help magnify the view and will make the red coloration brighter and easier to see.

Amateur astronomers can actually make some useful observations during total eclipses. It's impossible to predict exactly how dark the Moon will appear during totality. The color can also vary from dark gray or brown, through a range of shades of red and bright orange. The color and brightness depend on the amount of dust in Earth's atmosphere during the eclipse.

Unlike solar eclipses, lunar eclipses last much longer. The maximum time a lunar eclipse can last is 3 hours and 40 minutes and the longest time the Moon can stay in totality is 1 hour 40 minutes.

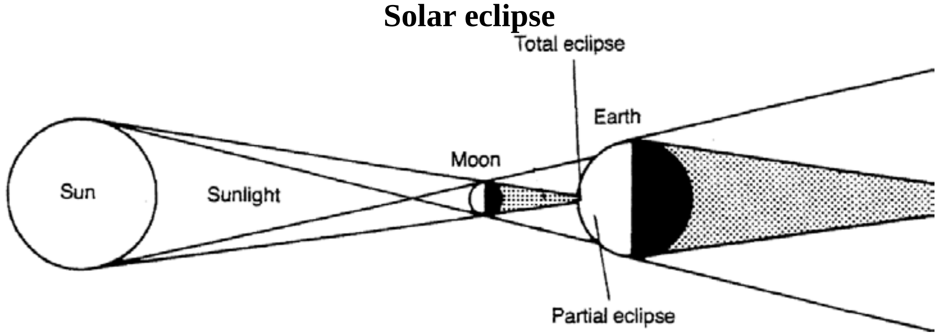
Eclipse Frequency and Future Eclipses

During the five millennium period from 2000BC through 3000 AD, there are 7,718 eclipses of the Moon (including both partial and total). There are anywhere from 0 to 3 lunar eclipses (not including penumbral) each year. Approximately one total lunar eclipse is visible from North America per year.

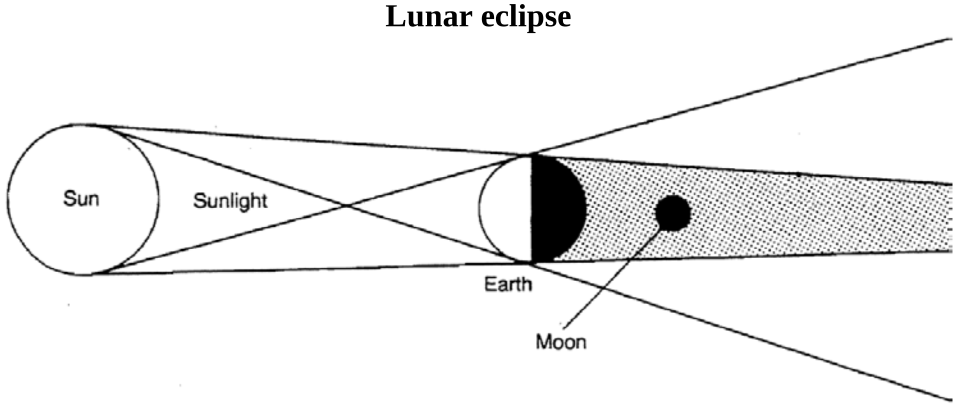
Fun Eclipse Facts

- Eclipses very often occur in threes, alternating lunar, solar and lunar.
- A Solar eclipse always occurs two weeks before or after a lunar eclipse.
- Solar eclipses can occur at least 2 and no more than 5 times a year.

Solar eclipse



Lunar eclipse



Analysis:

Answer the following questions on lined paper.

Solar Eclipses

1. What phase must the moon be in to produce a solar eclipse?
2. How often do solar eclipses occur (on at least one place) on Earth?
3. What does it mean to be in the umbra of a solar eclipse? What would you see if you were in the umbra of a solar eclipse?
4. What does it mean to be in the penumbra of a solar eclipse? What would you see if you were in the penumbra of a solar eclipse?
5. Draw a Venn Diagram comparing and contrasting Penumbra and Umbra.
6. Why must one use special glasses or filters when observing a solar eclipse?
7. What is the path of totality?
8. What is an annular eclipse?
9. What causes annular eclipses to occur?
10. Draw a Venn Diagram comparing and contrasting annular and total solar eclipses.
11. How does the length of total solar lunar eclipses and annular eclipses differ?
12. When is the next solar eclipse that will be visible from North America?
    According to figure 1, when will the next solar eclipse be visible from our location?

Lunar Eclipses

13. What phase must the moon be in to produce a lunar eclipse?
14. What happens to the color of the Moon when a lunar eclipse occurs?
15. What causes the color of the Moon to change during a lunar eclipse?
16. How long does a lunar eclipse last for?
17. Using figure 2, when will the next lunar eclipse be visible for our location?
18. What astrological event can clue you in to the upcoming occurrence of an eclipse?
19. Would more people be able to view a solar eclipse or a lunar eclipse? Why?
20. What did you find most interesting about eclipses?

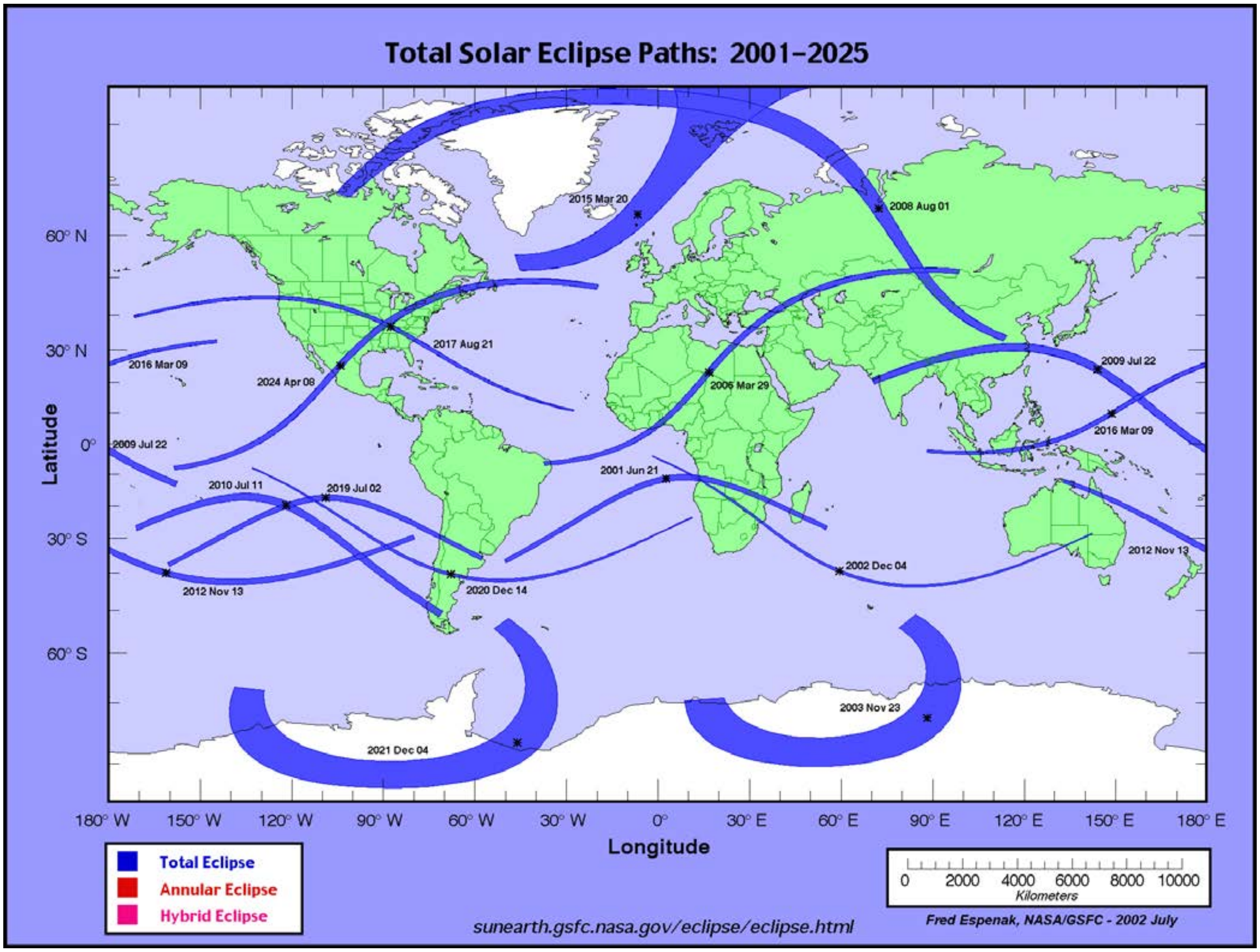


Figure 1

Lunar Eclipses: 2008 - 2015				
Calendar Date	Eclipse Type	Umbral Magnitude	Partial/Total Duration	Geographic Region of Eclipse Visibility
(Link to Figure)				*(Link to RASC Observers Handbook)*
2012 Jun 04	Partial	0.370	02h07m	Asia, Aus., Pacific, Americas
2012 Nov 28	Penumbral	-0.187	-	Europe, e Africa, Asia, Aus., Pacific, N.A.
2013 Apr 25	Partial	0.015	00h27m	Europe, Africa, Asia, Aus.
2013 May 25	Penumbral	-0.934	-	Americas, Africa
2013 Oct 18	Penumbral	-0.272	-	Americas, Europe, Africa, Asia
2014 Apr 15	Total	1.291	03h35m **01h18m**	Aus., Pacific, Americas
2014 Oct 08	Total	1.166	03h20m **00h59m**	Asia, Aus., Pacific, Americas
2015 Apr 04	Total	1.001	03h29m **00h05m**	Asia, Aus., Pacific, Americas
2015 Sep 28	Total	1.276	03h20m **01h12m**	e Pacific, Americas, Europe, Africa, w Asia

Geographic abbreviations (used above): n = north, s = south, e = east, w = west, c = central

Figure 2

Solar Eclipses: 2011 - 2020						
Calendar Date	TD of Greatest Eclipse	Eclipse Type	Saros Series	Eclipse Magnitude	Central Duration	Geographic Region of Eclipse Visibility
2011 Jan 04	08:51:42	Partial	151	0.858	-	Europe, Africa, c Asia
2011 Jun 01	21:17:18	Partial	118	0.601	-	e Asia, n N. America, Iceland
2011 Jul 01	08:39:30	Partial	156	0.097	-	s Indian Ocean
2011 Nov 25	06:21:24	Partial	123	0.905	-	s Africa, Antarctica, Tasmania, N.Z.
2012 May 20	23:53:53	Annular	128	0.944	05m46s	Asia, Pacific, N. America [Annular: China, Japan, Pacific, w U.S.]
2012 Nov 13	22:12:55	Total	133	1.050	04m02s	Australia, N.Z., s Pacific, s S. America [Total: n Australia, s Pacific]
2013 May 10	00:26:20	Annular	138	0.954	06m03s	Australia, N.Z., c Pacific [Annular: n Australia, Solomon Is., c Pacific]
2013 Nov 03	12:47:36	Hybrid	143	1.016	01m40s	e Americas, s Europe, Africa [Hybrid: Atlantic, c Africa]
2014 Apr 29	06:04:32	Annular	148	0.987	-	s Indian, Australia, Antarctica [Annular: Antarctica]
2014 Oct 23	21:45:39	Partial	153	0.811	-	n Pacific, N. America
2015 Mar 20	09:46:47	Total	120	1.045	02m47s	Iceland, Europe, n Africa, n Asia [Total: n Atlantic, Faeroe Is, Svalbard]
2015 Sep 13	06:55:19	Partial	125	0.788	-	s Africa, s Indian, Antarctica
2016 Mar 09	01:58:19	Total	130	1.045	04m09s	e Asia, Australia, Pacific [Total: Sumatra, Borneo, Sulawesi, Pacific]
2016 Sep 01	09:08:02	Annular	135	0.974	03m06s	Africa, Indian Ocean [Annular: Atlantic, c Africa, Madagascar, Indian]
2017 Feb 26	14:54:32	Annular	140	0.992	00m44s	s S. America, Atlantic, Africa, Antarctica [Annular: Pacific, Chile, Argentina, Atlantic, Africa]
2017 Aug 21	18:26:40	Total	145	1.031	02m40s	N. America, n S. America **[Total: n Pacific, U.S., s Atlantic]**
2018 Feb 15	20:52:33	Partial	150	0.599	-	Antarctica, s S. America
2018 Jul 13	03:02:16	Partial	117	0.336	-	s Australia
2018 Aug 11	09:47:28	Partial	155	0.737	-	n Europe, ne Asia
2019 Jan 06	01:42:38	Partial	122	0.715	-	ne Asia, n Pacific
2019 Jul 02	19:24:07	Total	127	1.046	04m33s	s Pacific, S. America [Total: s Pacific, Chile, Argentina]
2019 Dec 26	05:18:53	Annular	132	0.970	03m39s	Asia, Australia [Annular: Saudi Arabia, India, Sumatra, Borneo]
2020 Jun 21	06:41:15	Annular	137	0.994	00m38s	Africa, se Europe, Asia [Annular: c Africa, s Asia, China, Pacific]
2020 Dec 14	16:14:39	Total	142	1.025	02m10s	Pacific, s S. America, Antarctica [Total: s Pacific, Chile, Argentina, s Atlantic]

Geographic abbreviations (used above): n = north, s = south, e = east, w = west, c = central

Figure 3

Tides

Introduction:
The word tides is a generic term used to define the alternating rise and fall in sea level with respect to the land, produced by the gravitational attraction of the Moon and the Sun to Earth. To a much smaller extent, tides also occur in large lakes, such as the Great Lakes, the atmosphere, and within the solid crust of the Earth.

Question: What are the tides and what causes them?

Background: *(write a few things that you already know pertaining to about the question above)*

Vocabulary:
Neap tide
Spring tide

Materials: This assignment packet

Procedure & Analysis:
Read through the following passages and answer the questions that follow on lined paper..

Lunar Tides

Tides are the rise and fall of the ocean's water every 12.5 hours or so. The force of gravity pulls the Moon and Earth toward each other. Tides occur mainly because of the differences in how much the Moon pulls on different parts of the Earth but also include the force of the Sun's pull on Earth. As the Earth rotates, the Moon's gravity pulls water toward the point on the Earth's surface closest to the Moon. The Moon pulls least on the side of the Earth farthest away. Two tides occur each day because of this difference in the pull of the Moon's gravity.

Twice a month, the Moon, Earth, and the Sun are in a straight line. The combined forces of the gravity of the Sun and Moon produce an especially high tide called a spring tide and an especially low tide. Also, twice per month, the pull of the gravity of the Sun and Moon are at right angles to each other. At those times, the high tide is lower than usual, and is called a neap tide. The low tides then are higher than normal.

High and Low Tides

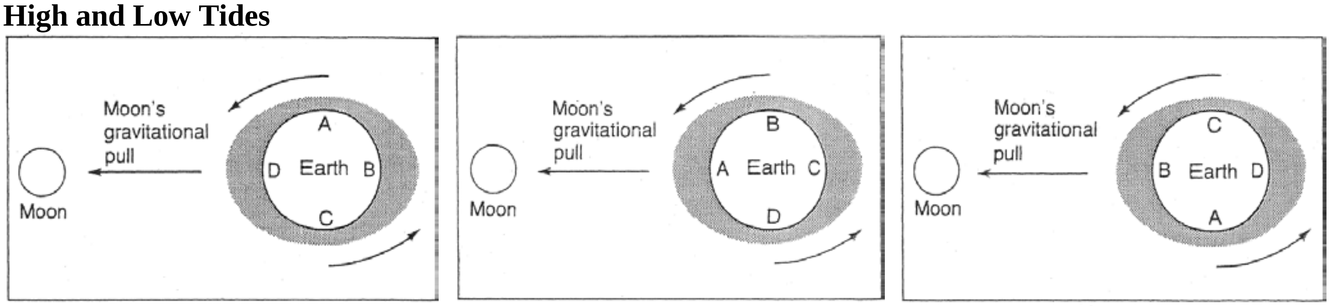


Figure 1 Figure 2 Figure 3

Use Figure 1 on the front page to answer questions 1 and 2.
1. Which side of the earth is facing the moon?
2. Which sides of the earth are having low tide? High tide?
    Use Figure 2 on the front page to answer questions 3 and 4.
3, Which sides of the earth are having low tide? High tide?
4. How much time has passed between Figures 1 and 2?
    Use Figure 3 on the front page to answer questions 5 and 6.
5. Which sides of the earth are having high tide? Low tide?
6. How much time has passed between Figures 2 and 3?

Spring Tides

A. Spring Tides

When the moon is at its full and new phases, the earth has higher high tides and lower low tides than at other times. These tides are called spring tides and they occur twice a month, when the sun and the moon line up with the earth. The increased effect of the sun's gravity on the earth causes the ocean bulges to become larger.

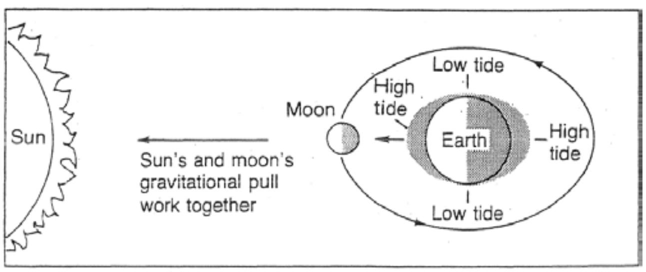


Figure 1 New moon

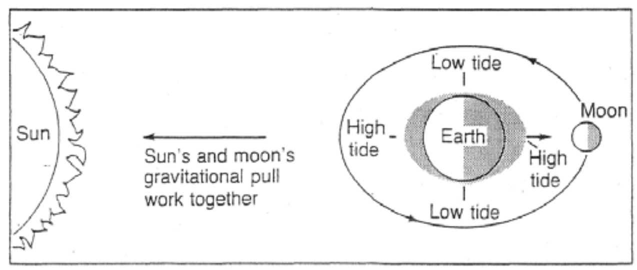


Figure 2 Full moon

7. When are the sun, moon, and earth in a line?
8. What happens to the pull of gravity on the earth when the sun, earth, and moon are in a line?
9. What are the unusually high and low tides called?
10. How often do the unusually high and low tides occur?
11. At which moon phases do the springtides take place?

Neap Tides

During the first- and last-quarter phases, the moon's gravitational pull on the oceans is partially canceled out by the sun's gravitational pull. This results in tides that are not very high and not very low. These tides are called neap tides and they occur twice a month.

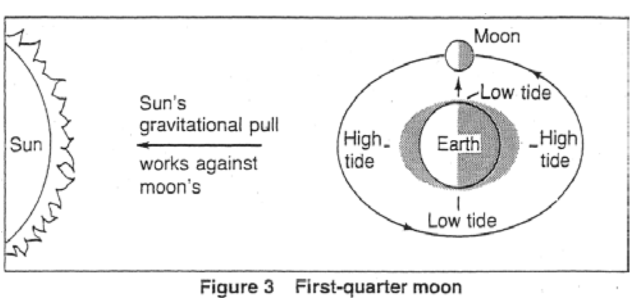


Figure 3 First-quarter moon

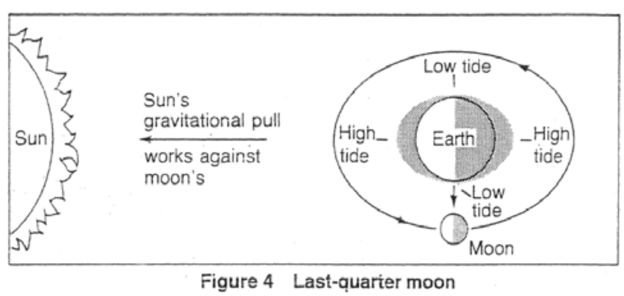


Figure 4 Last-quarter moon

12. When are the moon and the sun at right angles?
13. What happens to the pull of gravity when the moon and sun are at right angles?
14. What kinds of tides occur when the moon and sun are at right angles?
15. What are the tides that are not very high and not very low called?
16. How often do these tides occur?
17. At which moon phases do these tides take place?

The Universe – The Moon *(This video can also be watched on Netflix Streaming)*

Answer the following questions on a separate sheet of paper. You do not need to answer them in complete sentences. Questions are spaced out with enough time for you to answer each (1-3 minutes apart).

1. How many moons are there in the solar system? What planets have them?

2. How long is a single day on the moon?

3. What color would the sky appear if you were on the Moon?

4. What is lunar regolith?

5. Why were the flat spots on the Moon called Maria (pronounced Mar-E-a)

6. What caused the mountains on the Moon

7. How many days are there per month in a lunar calendar?

8. How does the moon cause the tides?

9. How does the Moon help create the conditions necessary for life on Earth?

10. Who was the first person to look at the Moon with a telescope?

11. In 1873, Edward Rouche hypothesized that the Earth was formed from what?

12. Why is Rouche's theory wrong?

13. How much is the Moon moving away from the Earth?

14. Darwin believed that as the Moon and Earth were closer together, what happened to their speed?

15. What was the Capture Theory?

16. What is the flaw in the Capture Theory?

17. What type of rocks were found on the moon?

18. What does the oxygen isotope ratio tell us about the Moon?

19. In 1972, a computer model was used to simulate how the solar system formed. The simulation showed that the Earth formed very close to a planet the size of which current planet?

20. What is the Giant Impact Theory?

21. What happened to the "inner clump" that was left after the collision?

22. How long did it take for the Earth to resume its spherical shape after the giant impact?

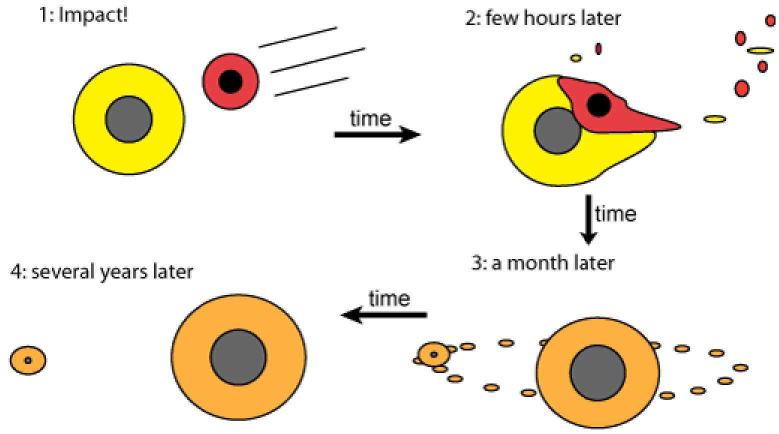
23. Why might we want to revisit the Moon?

24. Should our government spend the money to revisit the Moon? Why/why not?

Clues to Lunar History

Introduction:

A large object that struck Earth about 4.0-4.5 billion years ago is credited with creating conditions that resulted in the formation of our Moon. It is sometimes referred to as The Giant Impact Theory. It explains evidence collected from Earth and Moon rocks that were collected by the Apollo astronauts in the 1970s. The Moon probably looks today much like it did within the first months to years of its formation. Impact events occurred immediately and repeatedly, changing the newly formed lunar surface to the image of the Moon we see in our night sky.



A long time ago in a planet system close to home...
A giant impact made the Moon. The Moon is mantle material from the Earth and impactor. Earth today is mantle+core from early Earth + impactor.

Giant Impact Theory of Lunar Formation

Approximately 4.0 billion years ago, a planet-sized object smashed into our still forming Earth. The impact was so great that it nearly split our planet apart- instead vast amounts of molten material were splashed out into space and quickly solidified in the cold temperatures there. The debris orbited Earth but formed quickly, forming our only natural satellite, the Moon. Estimates made by computer modeling of this process estimate the time required for the Moon to begin to form as one solid body was only about 24 hours. As the accreting material increased in mass, the increasing pressures at the core were high enough to melt the inner portions of the Moon. In the early 1970s Apollo astronauts observed small lunar quakes taking place with special seismographs. These weak lunar quakes indicate that the Moon is not entirely solidified, but remains partially molten at great depths.

Impacts occurred during and immediately following the formation of the Moon. These Large (and some small) impact basins remain preserved on the lunar surface. Since large of meteors in orbit remained around Earth after the Moon formed, Earth too, was bombarded by numerous meteorites from this event. Unlike Earth however, the Moon has no atmosphere to weather away this evidence of ancient bombardment. No atmosphere means no weather (clouds, precipitation, ice, wind, etc.). Without an atmosphere, impacts Apollo astronauts' footprints) remain on the lunar surface indefinitely.

Highlands Maria

There are two basic types of surface materials on the Moon. There are the Highlands and the Maria (pronounced mar-e-a). The Highlands are composed of a light-colored rock called anthracite. Because anthracite reflects light better than the darker basalt of the Maria regions, the Highlands appear brighter. The Highlands are older than the Maria.

The "mare" or maria is Latin for "sea." These areas are made of dark igneous basalt. Basalt is also formed naturally on Earth- where lava solidifies near or on Earth's surface; it solidifies to fine-grained igneous rock. Geologists use a principle called Uniformitarianism to figure out how events worked in the past by studying what occurs around us today. The concept is that processes that occurred in the distant past probably don't occur too differently than those same processes do today. By studying the processes of basalt formation on Earth, planetary geologists who studied the moon rocks were able to determine a probable means of its formation on the Moon.

Shortly after its formation, large asteroid-sized objects bombarded the freshly formed surface of the Moon. Some of these impacts were so large, that they essentially cracked the Moon's surface open, allowing some of the molten material to seep out. This "lava" flowed out under pressure and filled in the lower elevations (maria) of the lunar surface. Using basic principles of Relative Age dating, the sequence of impact basins can be put in order. Couple this with evidence from radiometric dating and a much more complete picture of lunar history can be pieced together.

Question: How do we know how the Moon was formed?

Background: *(write a few things that you already know pertaining to about the question above)*

Materials

Photographs of lunar surface visible to Earth, 6
Labeled drawings of the lunar surface visible to Earth, 2
Scissors
Glue sticks

Vocabulary:

Accrete
Highlands
Maria

Procedure:

1. Carefully cut out the six detailed photographs of the lunar surface- it will be important to leave a little white border where the pictures overlap so you can glue them together. Carefully situate them on your desk to match up the gray areas prior to gluing them as they look very similar. Once you are sure they are in the right order, glue them together to form a mosaic picture of the lunar surface.

2. Locate and label the following features on the mosaic of the lunar surface.

Lunar feature	Age scale
a. Rheita Valley	
b. Lunar highlands near the South Pole	
c. Mare Crisium lava flows	
d. Archimedes impact crater	
e. Copernicus impact crater	
f Aristillus impact crater	
g. Eratosthenes impact crater	
h. Mare Imbrium impact crater	
i. Mount Pico	
j. Tycho impact Crater	
k. Kepler impact crater	
l. Mare Tranquillitatis	

Figure 1

3. Determine the relative ages of these features on the basis of the three principles listed below and figure 1. Assign numbers to each of the features (1-10) to the right of the feature name in figure 2. (1 is the oldest, while 10 is the youngest).

Principle of Superposition - Younger formations sit atop older formations. Examples: Small craters inside larger ones are always younger than the larger craters. Craters sitting atop lava flows are always younger than the lava flows. Likewise, impact basins or craters filled with lava flows are older than the lava flows that filled them.

Principle of Cross-Cutting Relationships - Younger features always cut across older features. Examples: Bright ejecta rays are thrown on top of existing features. The ejecta rays are younger because they cut across events that have already occurred.

Crater Counts- Old areas of the lunar surface are blanketed with craters while younger areas are not. The oldest regions of the lunar surface house the largest impact basins, while younger areas have smaller craters.

Radiometric Dates of Prominent Lunar Surface Features

Type of Surface Feature		Surface Feature Name	Absolute Age (b.y.o.)	Relative Age (b.y.o.)
Impact Event	Maria (Lavaflow)			
*		Tycho		.1
*		Copernicus		.9
*		Eratosthenes		2.0 (?)
	*	Oceanus Procellarum	3.29-3.08	
	*	Eratosthenes Basalts	3.2	
	*	Mare Crisium	3.3	
	*	Mare Imbrium	3.3-3.7	
	*	Mare Fecunditatis	3.41	
	*	Mare Tranquillatiatis	3.57-3.88	
*		Archimedes		3.8 (?)
	*	Mare Serenitatis	3.65-3.85	
*		Mare Imbrium (including ,A pennine Mts.)	3.85	
*		Mare Serenatatis	3.87	
*		Mare Crisium		
*		Mare Nectaris	3.92	
*		Mare Fecunditatis		
*		Marae Tranquillatatis		
		Oldest Mare Basalt within a Highland Breccia	4.2	
		Oldest Highland rock within a Breccia	4.356	

Figure 2

Analysis:
Answer the following questions on lined paper.

1. About how old is the Moon?

2. What is the name given to the widely accepted theory of how the moon was formed?

3. According to the G.I.T., how was the Moon formed?

4. How long did it take for the Moon to coalesce while it was forming?

5. In the introduction, what is meant by the “accretion of material?”

6. How do we know that the core of the Moon is still molten?

7. Since it was formed, what events have changed the appearance of the Moon?

8. Why might a meteor impact more than a billion years old still be visible on the Moon while a meteor impact on Earth that is the same age NOT be visible?

9. Draw a Venn Diagram comparing highlands and maria.

10. What is uniformitarianism?

11. How were the smooth spots on the Moon created?

12. Which came first, the impact crater or the lava flow?

13. Why do you think the lunar Maria be named after "seas"?

14. Why is it important to understand the geography of the moon?

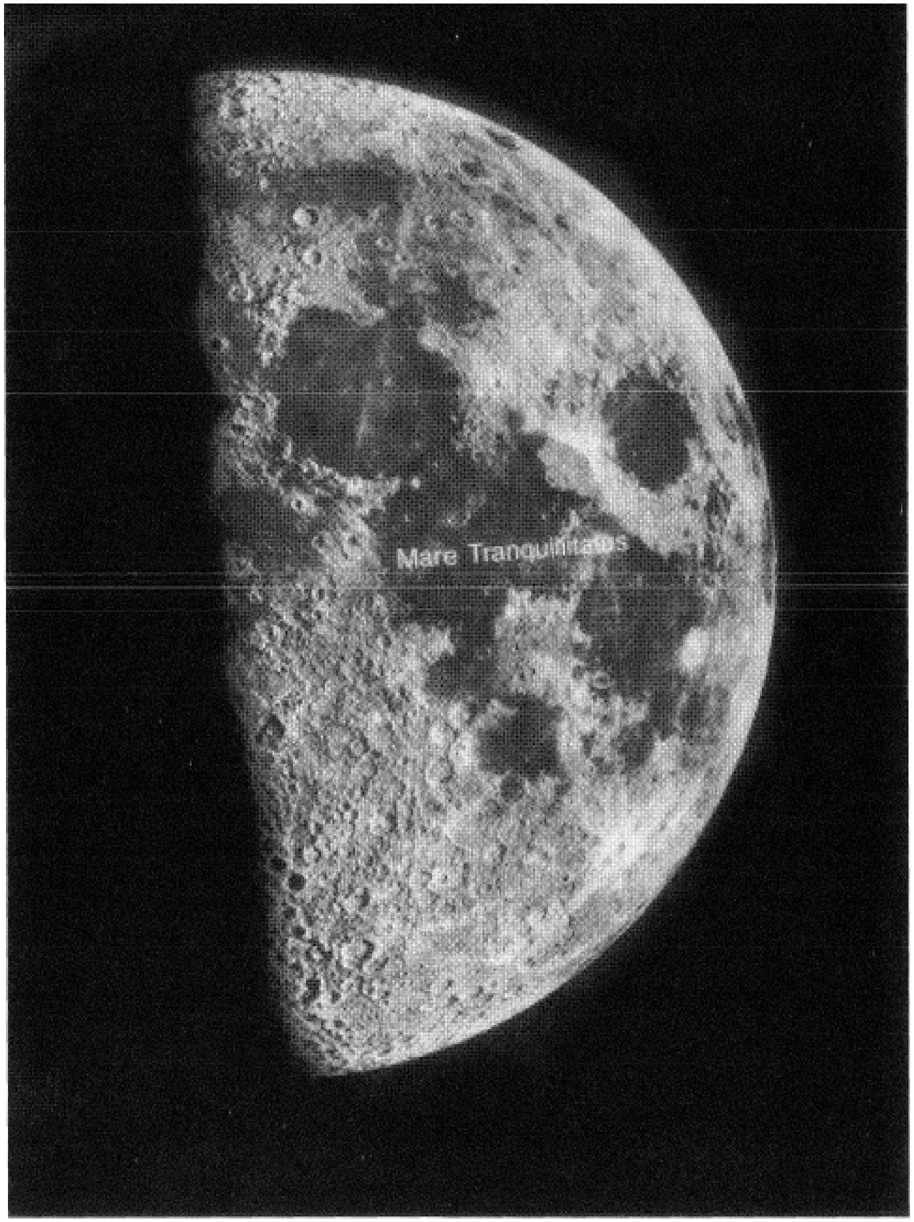
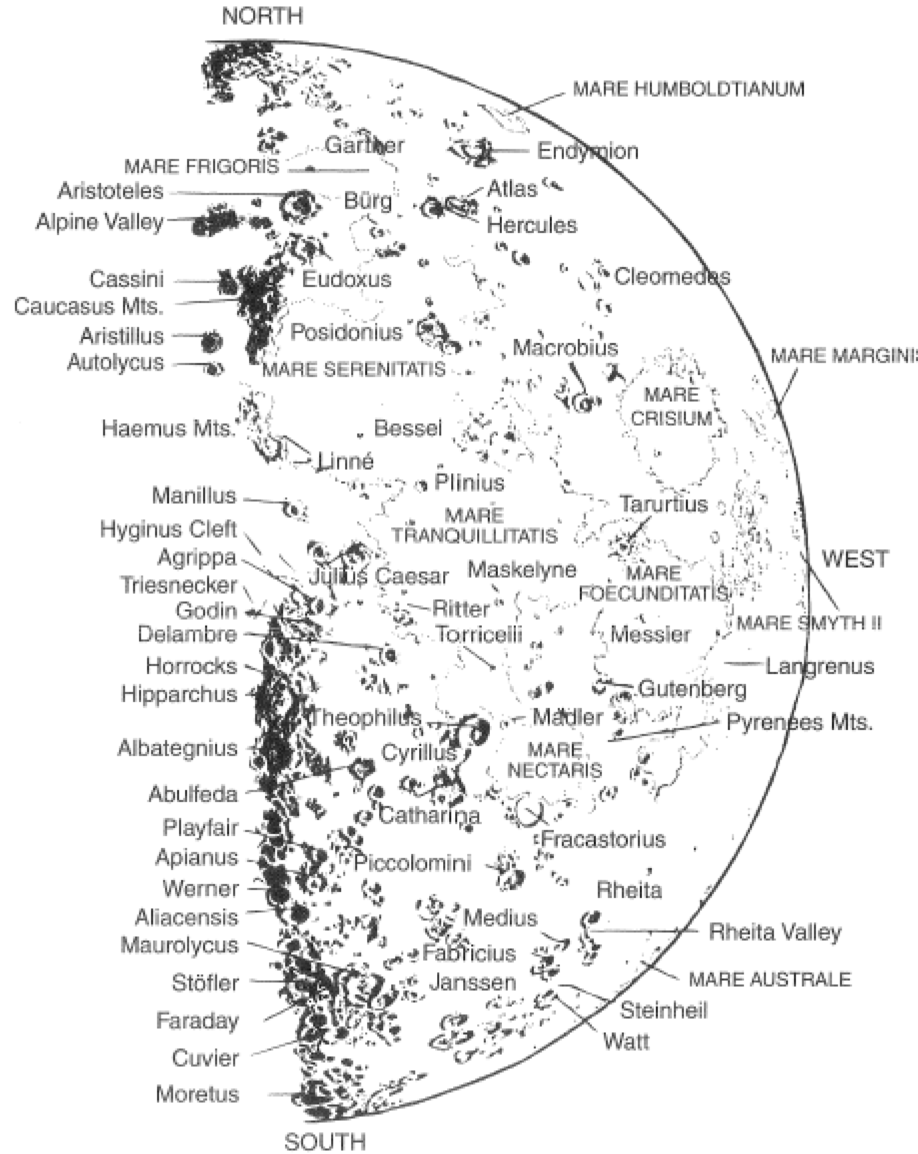


Figure A. First-quarter Moon (7 days old).



Key to First-quarter Moon

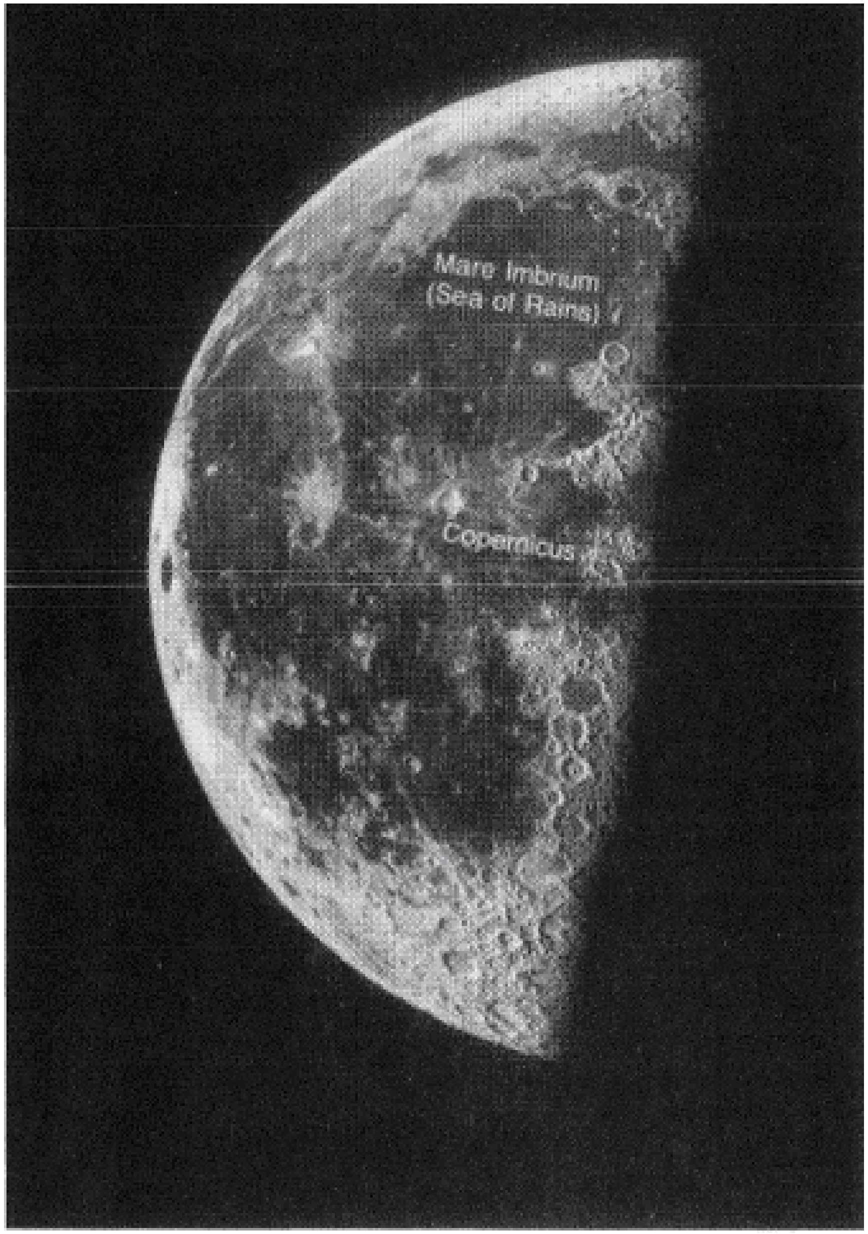
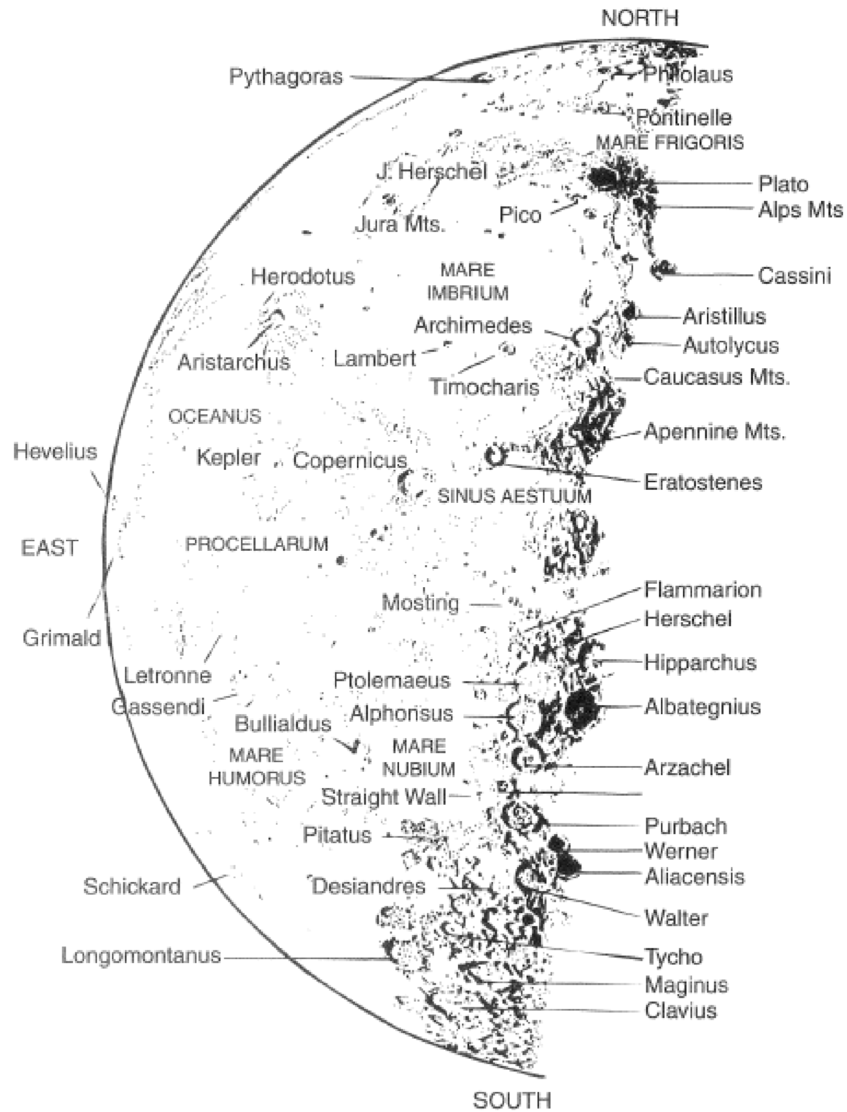


Figure B. Third-quarter Moon



Key to Third-quarter Moon

Geology of the Moon Reading

Introduction:
In many ways the Moon is a geologic Rosetta stone: an airless, waterless body untouched by erosion, containing clues to events that occurred in the early years of the solar system, which have revealed some of the details regarding its origin and providing new insight about the evolution of Earth. Although they also posed new questions, the thousands of satellite photographs brought back from the Moon have permitted us to map its surface with greater accuracy than Earth could be mapped a few decades ago.

We now have over 380 kg of rocks from nine places on the Moon, rocks that have been analyzed by hundreds of scientists from many different countries. Data from a variety of experiments have revealed much about the Moon's deep interior. As it turns out, the Moon is truly a whole new world, with rocks and surface features that provide a record of events that occurred during the first billion years of the solar system. This record is not preserved on Earth because all rocks formed during the first 800 million years of Earth's history were recycled back into the interior.

Question: What are the geologic features of our Moon and what caused them?

Background: (write a few things that you already know pertaining to the above question)

Materials: This handout

Vocabulary:
Highlands
Maria
Impact craters
Basalt
Anorthosite
Regolith

Procedure:
Read through the following passage.

Major Geologic Provinces
When Galileo first observed the Moon through a telescope, he discovered that its dark areas are fairly smooth and its bright areas are rugged and densely pockmarked with craters. He called the dark areas maria, the Latin word for seas, and the bright areas terrae (highlands). These terms are still used today, although we know the maria are not seas of water and the highlands are not geologically similar to Earth's continents. The maria and highlands do, however, represent major features of the lunar surface.

The maria and highlands can even be distinguished from Earth by the naked eye. The maria on the near side of the Moon appear to be dark and smooth, with only a few large craters. Some maria occur within the walls of large circular basins. We know from lunar rock specimens and surface features that the maria are vast layers of thin basaltic lava, which flowed into depressions and flooded large parts of the lunar surface.

The highlands, make up about two-thirds of the near side of the Moon. The highlands have the highest and most rugged topography on the Moon. An important characteristic of the lunar highlands is that they contain tens of thousands of craters, many of which range from 50 to 1000 km in diameter.

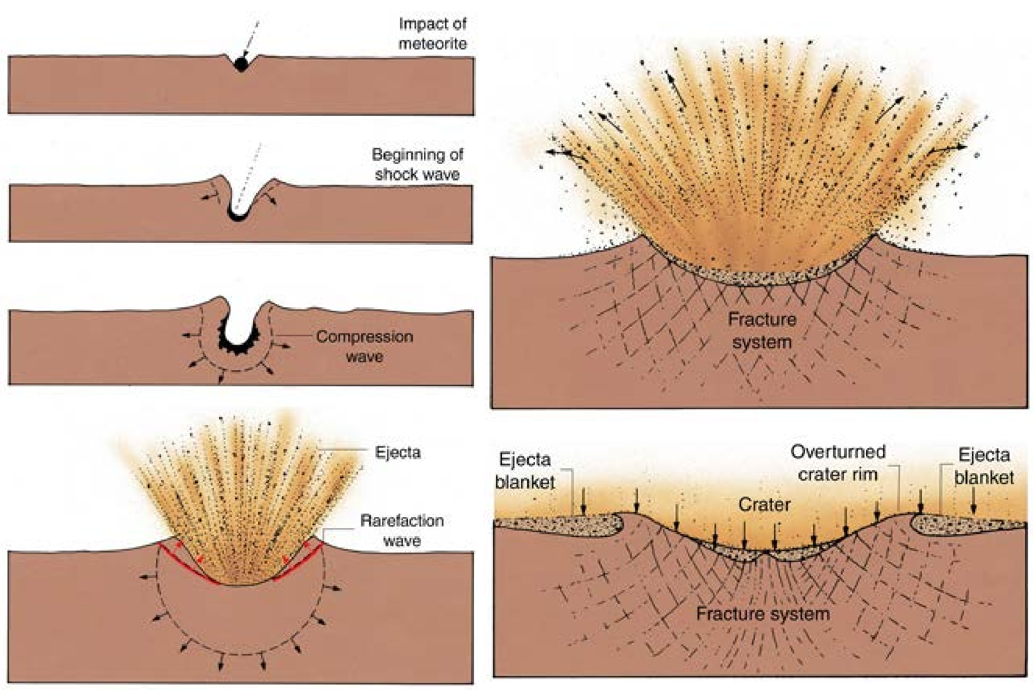
The far side of the Moon was totally unknown until photographs were first taken by a Soviet spacecraft in 1959. It was a total surprise to learn that, although the details were poorly defined, the far side of the Moon was composed almost entirely of densely cratered highlands. Why the maria are largely restricted to the near side of the Moon remains a fundamental question of lunar geology.

The maria and highlands are composed of distinctly different rock types. Rocks collected by Apollo astronauts show the highlands to be mostly composed of anthracite rocks, in contrast to the dark basaltic maria. The maria and highlands not only represent different types of terrain, they broadly represent two different periods in the history of the Moon. The highlands, which occupy about 80 percent of the entire lunar surface, are composed of rocks that formed very early in the Moon's history. The entire outer portion of the Moon is thought to have been molten at the time the highlands crust began to form 4.6 billion years ago.

As minerals accumulated they formed a crust, which soon became densely cratered by an intense bombardment of meteorites. The maria were formed by the eruption of vast amounts of lava that accumulated in the lowlands of large craters or basins and, in places, overflowed and spread over parts of the lunar highlands. The maria are thus relatively young features of the lunar surface, even though they began to form four billion years ago.

Impact Craters

Impact cratering is a rare event on Earth today but early in its history was quite common. The Moon is pockmarked with literally billions of craters, which range in size from microscopic to huge, circular basins hundreds of kilometers in diameter.



Crater Degradation

Once a crater is formed, it may then be modified by a number of processes that gradually change the appearance of the crater until it may be totally unrecognizable or obliterated. These changes that wear away at the original crater are called crater degradation. Later impacts may partly or completely destroy the older crater or the crater may be covered with dust and debris ejected from a younger crater. The crater may be partially or completely buried by lava flows or even buried in sedimentary deposits.

Volcanic Features

Volcanic activity is especially important in studies of planetary evolution because volcanoes allow us to see what type of rock and material can be found within the interior. The maria were formed by vast floods of basaltic lava and the Moon has a spectacular volcanic history. The highlands, too, have some volcanic rocks, but volcanic landforms are not as obvious there.

Lunar Rocks

To some people the rocks returned from the Moon were a disappointment. Few exotic minerals were found. Instead, Moon rocks are like the common rocks found on Earth. Yet these lunar rocks hold the key to understanding the thermal and chemical evolution of the Moon. This lunar material consists of several types of igneous rocks as well as rocks created by meteoritic bombardment.

Anthracite:

Anthracite is a coarse-grained igneous rock composed almost entirely of the mineral plagioclase. This rock type was collected from the lunar highlands it forms a group of rocks that are the most abundant and oldest (greater than 4.4 b.y.o.) on the lunar surface. Shortly after the accretion of the Moon, its outer layers melted to form a global "ocean" of molten rock. Crystallization within this "magma ocean" produced anthracite which floated to the surface which coalesced to form the lunar crust.

Lunar Basalt:

Most of the igneous rocks collected from the Moon's maria are very similar to basalt, the most common rock in Earth's crust. As the Moon's magma ocean cooled, crystallization and removal of various minerals gradually changed the composition of the remaining melt. Lunar basalt contains more iron giving it a darker color and greater density. Geologists believe that the basalt arose on the moon much as it did on Earth.

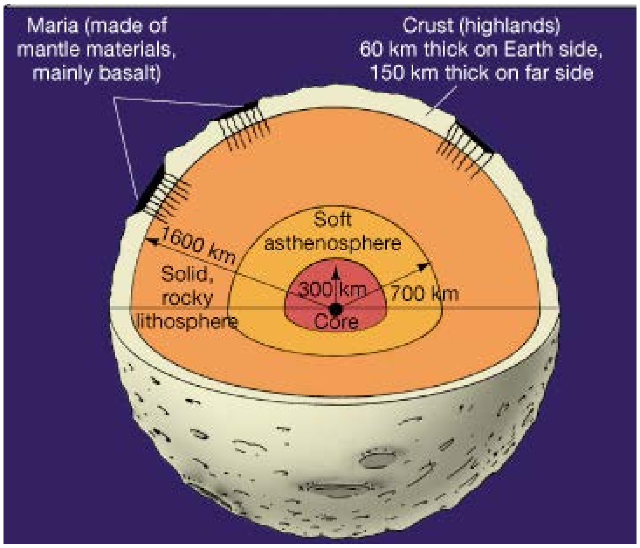
Regolith:

The Moon's surface is covered in most places by a thin layer of relatively loose fine powder called regolith. Regolith on the Moon consists of debris thrown out of craters, the main cause of regolith. The average thickness of the regolith depends upon the age of the surface on which it has been formed. The older the surface, the thicker the regolith. The figure shows an Apollo astronaut’s boot print in the regolith.

Moon Interior

Due to the Moon’s average density being similar to the density of lunar surface rock, this eliminates any chance the Moon has a massive, and very dense nickel–iron core like that of Earth. In fact, the low density implies that the entire Moon is actually deficient in iron and other heavy metals compared to our planet. There is no evidence for any large-scale lunar magnetic field which requires a rapidly rotating liquid metal core, like Earth’s.

However, the inner parts of the core may be at least partially molten. The core is surrounded by a roughly 400-km-thick inner mantle much like the Earth. Above these regions lies the solid crust material, which forms the lunar highlands.



The crust on the lunar far side is thicker than that on the side facing Earth. If we assume that lava takes the line of least resistance in getting to the surface, then we can readily understand why the far side of the Moon has no large maria—volcanic activity did not occur on the far side simply because the crust was too thick to allow it to occur there.

But why is the far-side crust thicker? The answer is probably related to Earth's gravitational pull. Just as heavier material tends to sink to the center of Earth, the denser lunar mantle tended to sink below the lighter crust in Earth's gravitational field. The effect of this was that the crust and the mantle was pulled a little closer to Earth, while the crust moved slightly away. Thus, the crust became thinner on the near side and thicker on the far side.

The Moon Today

Today, the Moon does not have a significant source of internal energy nor a tectonic system like Earth. It has no continents nor ocean basins and no deformed rocks resulting from mountain building. Moreover, it has no atmosphere or surface fluids, so it lacks weather to modify its surface. Small planetary bodies like the Moon cooled much faster than larger ones. Its thermal and tectonic evolution proceeded at an accelerated pace and stopped when the lithosphere became so thick that it could no longer be deformed.

Analysis:

Answer the following questions on a separate sheet of paper.

1. List the stages of a crater by the impact of a meteorite and briefly describe what geologic features are produced by impact?
2. How are lunar craters modified as time passes?
3. Why are there fewer craters on the lunar maria than on the highlands?
4. Why are there so few impact craters on Earth as compared to the Moon?
5. How do we know the moon does not have a dense iron core?
6. Why were so many people disappointed in the rocks brought back from the Moon?
7. What is responsible for the formation and modification of the lunar surface? Explain why.
8. Explain why there is a difference in the thickness of the crust between the side of the moon facing the Earth and the side that faces away from the Earth?
9. Draw a Venn diagram comparing anthracite and basalt.
10. What is regolith and how was it formed?
11. What is the Moon like today?
12. What would you still like to know about our Moon?