Teacher's Guide of Short Programs for

MEDIAGLOBE® DIGITAL PLANETARIUM

4
It's a Phase We're Going Through

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Ver.1.0

KONICA MINOLTA PLANETARIUM CO., LTD.

The essentials of imaging
INTRODUCTION

First of all don't panic at the size of this booklet! You are not expected to cover ALL of the following material. However, we would like you to pick and choose the activities from each Lesson that you think will cover the Big Ideas and the Leading Questions.

The Unit Concepts are classified as follows:
Moon Phases, Eclipses, Tides and the Space Race. This unit is designed as a practical application guide. This means everything learned in this unit can be applied to the real sky.

To complete the Unit Concepts it would be helpful if you and your class visit a Media Globe/Planetarium Facility at least twice during the school year.

PHILOSOPHY

The philosophy for this booklet is: sequential learning by practical application. Hopefully, learning will occur by the repeated use of terms and concepts handed down from one activity to another. This along with hands-on practical application activities will produce the outcomes vital to the learning process.

Astronomy is not just looking at the stars. Astronomy spans many subjects like: Geography, History, Geometry, Trigonometry, Biology, Chemistry, Physics, Philosophy, Religion and the pseudo science of astrology. This sequential course of astronomy will cover or touch upon all of those subjects.

Finally, a Media Globe/Planetarium facility gives us the opportunity to explore every ancient point of light that our ancestors recognized as stars and planets. By studying other worlds, we will better understand our own.

GENERAL OBJECTIVE

We believe the Media Globe/Planetarium Facility should be a place where learning can be exciting. Here, the students will be able to apply or see the application of the lessons they learned in this booklet.

WEB LINKS TO THE VARIOUS ACTIVITIES:

Abrams Planetarium: www.pumsu.edu/abrams/diary.html
Jet Propulsion Laboratory: www.jpl.nasa.gov
NASA Education: www.education.nasa.gov
Paper Plate Astronomy: http://analyzer.depaul.edu/paperplate
Transit of Venus: http://analyzer.depaul.edu/paperplate/transit.htm
**UNIT CONCEPTS: Moon Phases, Eclipses, Tides, Geology**

<table>
<thead>
<tr>
<th>BIG IDEAS</th>
<th>GUIDING QUESTIONS</th>
</tr>
</thead>
</table>
| A. Lunar phases are caused the changing angular separation between the Moon and the Sun caused by the Moon orbiting the Earth, resulting in varying amounts of reflected moonlight. | 1. Why does the Moon go through phases?  
2. What is the name of each major phase and the angular separation between the phase and the Sun? |
| B. The Moon orbits the Earth counterclockwise as viewed from the North Star; and, west to east as viewed from the Earth’s surface.  
- The Moon travels approximately 120° to the east per day around the Earth.  
- The Moon will rise approximately 50 (48) minutes later each day. | 1. How many degrees does the Moon move in its orbit around the Earth in one day?  
2. Will the Moon rise earlier or later each month?  
3. How much earlier or later will the Moon rise day? Do we add or subtract in our calculation. |
| C. A Solar Eclipse occurs when the New Moon passes between the Earth and the sun.  
- A Lunar Eclipse occurs when the Full Moon passes into the Earth’s shadow.  
- A total Solar Eclipse lasts a few minutes, whereas a total Lunar Eclipse lasts a few hours.  
- New Moons and Full Moons are usually above or below the Sun and Earth respectively.  
- There is a slight wobble in the Moon’s orbital path around the Earth. | 1. What causes a Solar Eclipse?  
2. What causes a Lunar Eclipse?  
3. Why aren’t there Lunar and Solar eclipses each month?  
4. Which total eclipse lasts the longest: Solar or Lunar? |
| D. A First Quarter Moon will always rise at noon; be directly south at sunset; and, will set at midnight.  
- A Full Moon will always rise at sunset; be directly south at midnight; and, set at sunrise.  
- A Third Quarter Moon will always rise at midnight; be directly south at sunrise; and, set at noon. | 1. What time does a First Quarter Moon always: rise, be directly south and set?  
2. What time does a Full Moon always: rise, be directly south and set?  
3. What time will a Third Quarter Moon always: rise, be directly south, and set? |
| E. If you were on the Moon observing the Earth for one month you’d see that the Earth goes through all the phase of the Moon  
- If you’re on the Moon during its First Quarter phase you’d see the Earth in its Third Quarter phase. The Earth phase is always opposite the Lunar phase. | 1. Does the Earth go through phases like our Moon?  
2. If you’re on the Moon during its First Quarter phase what phase is the Earth?  
3. What conclusion can you make about the Lunar phase and the Earth phase? |
<table>
<thead>
<tr>
<th>Column A</th>
<th>Column B</th>
</tr>
</thead>
</table>
| F. The Terminator is the line that separates daytime from nighttime.  
-It's sunset on the Earth. You look up at the First Quarter Moon. The terminator of the Moon represents sunrise.  
-The terminator of the Moon, where shadows are the longest, is a great place to observe with a telescope because you can see lunar features in 3-D.  
-The only lunar phase that doesn't have a terminator is the Full Moon. | 1. What is the terminator as it relates to lunar phases?  
2. What does the terminator of a First Quarter Moon represent: sunrise or sunset?  
3. Why is the terminator of the Moon a an excellent place to observe with a telescope?  
4. Can we see the terminator of a a Full Moon? |
| G. The Moon and the Sun diameter multiplied by 108 gives the exact distance of the Moon and Sun respectively from the Earth.  
-Any round object held 108 times its diameter away from you will simulate the apparent size of the Moon and the Sun. This is how a small Moon can cover up a huge Sun in a Solar Eclipse. | 1. How many Moon diameters is the Moon away from the Earth?  
2. How many Sun diameters is the Sun away from the Earth?  
3. How does a very small Moon cover up a very large Sun during a Solar Eclipse? |
| H. A scale model of the Earth and Moon can explain the size and distance apart of each.  
-A scale model of the Sun, Earth, & Moon helps to explain size and distance relationships | 1. How would you use a scale model to explain the Earth & Moon in size and distance?  
2. How would you use a scale model to explain the Sun-Earth-Moon in size and distance? |
| I. Synchronous rotation means that the Moon rotates once in one orbit. | 1. How can one side of the Moon always face the Earth when the Moon is rotating? |
| J. Ocean tides occur everyday on the Earth because of the Moon's gravitational pull.  
-Everyday two high tides and two low tides occur causing a shoreline to change four times in one day.  
-The time between a high tide and a low tide is just under six hours.  
-When the Moon is near the horizon one will experience a low tide. Conversely, when the Moon is at its highest point in the sky or opposite one will experience a high tide.  
-The Earth's rotation is slowing down because of the Moon's gravity  
-The Moons rotation use to be much faster. | 1. What causes ocean tides and how often do they occur?  
2. How are high tides and low tides produced and how often do they occur?  
3. Calculate the time between a high tide and a low tide.  
4. What kinds of tides are produced when the Moon is on the horizon; and, at its highest point in the sky?  
5. Why is the Earth's rotation slowing down and by how much?  
6. Billions of years ago the Moon once rotated at a much faster rate. Why has is slowed down? |
| K. Once in a Blue Moon implies a long period of time. In reality, it refers to the interval of time between to two full Moons in one month; or, four full Moons in three months. The interval between these events is around 2.3 years. Regardless the full Moon is not blue | 1. What does “once in a blue” mean?  
2. What is a blue Moon?  
3. How long is the interval of time between blue Moons?  
4. Is the full Moon really blue? |
| L. The Moon came from the Earth | 1. What proof do we have that the Moon was once part of the Earth?  
2. Why are the rocks of the highland areas different than the rocks of the mare?  
3. Which rocks, highland or mare, have crystals and why?  
4. Explain how and when the Mare formed? |
|---------------------------------|------------------------------------------------------------------------------------------------|
| - The light gray rocks that make up the highland areas of the Moon have defined crystalline structures; whereas, dark rocks of the Mare have no crystal patterns  
-Slow cooling of magma produces crystalline structure; whereas, fast cooling produces no crystalline structures.  
-The Mare formed in two distinct ways. First, in the early formation of the Moon asteroids punched deep craters into the lunar surface. Several hundred million years later As the Moon’s interior heated up dark lava oozed across the floors of the Mare. | |
| M. Because the Moon has no atmosphere and therefore no weather, footprints left by the Apollo Astronauts will be there forever.  
-The Moon has no atmosphere because: The geologic activity (volcanoes), which produces atmospheres shut down billions of years ago. Also, there is not enough lunar gravity to hold on to an atmosphere if there were volcanoes  
-The Earth and the Moon are the same age. Since there is no weathering on the Moon the original moon rocks are in there original state.  
-Sedimentary rocks do not exist on the Moon because the Moon never had water. The particles for the sedimentary rocks are the result of weathering. Because there is no lunar atmosphere there is no weathering  
-Standing on the night side of the lunar surface one would not see stars twinkling because the Moon has no atmosphere. | 1. Why will footprints of the Apollo Astronauts last forever on the surface of the Moon?  
2. The Moon came from the Earth. The Earth has an atmosphere why then doesn’t the Moon have an atmosphere.  
3. The Earth and the Moon are the same age why then are Moon rocks older than Earth rocks.  
4. Give two reasons why the Moon doesn’t have sedimentary rocks?  
5. Why don’t stars appear to twinkle when one is standing on the night side of the Moon? |
| N The Moon Illusion The Moon appears to be very large when it is on the horizon and much smaller when it is high in the sky. This is an optical illusion that takes place when the brain compares the size of the Moon to distant objects on the horizon | 1. Why does the Moon (or Sun) appear to be very large when it is on the horizon; and, very small when it is high in the sky?  
2. Does the thickness of the Earth’s atmosphere have anything to do with this? |
| O | The U.S. entered into a “Race to the Moon” with the former Soviet Union purely because of politics.  
- the “Space Race” unofficially began in 1957; the race to the Moon began in 1961.  
- The U.S. had 12 men walk on the Moon; the Soviet Union because of problems with their big rockets never sent anyone to the Moon  
- The benefits of manned space travel to humans here on Earth far out way the costs. |

| P | Viewed naked eye from the Earth, the full Moon appears to have pictures like: The man on the Moon, a Rabbit, Jack and Jill, and a Frog. |

| 1. Why was there a competition with the former Soviet Union to see who could first land men on the Moon?  
2. How and when did the “Space Race” begin?  
3. How and when did the “Race to the Moon” begin?  
2. How many U.S. Astronauts land on the Moon; and how many Soviet Cosmonauts landed on the Moon?  
3. What benefits did the manned space program provide for humans here on the Earth? |

| 1. During a full Moon can one pick out the: Man on the Moon (actually there are two), a Rabbit, Jack and Jill, and a Frog? |
“It’s a Phase We’re Going Through”

Table of Contents

<table>
<thead>
<tr>
<th>Lesson</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Title Page</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Introduction</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Big Ideas/Leading Questions</td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>Table of Contents</td>
<td></td>
<td>3-6</td>
</tr>
<tr>
<td>Vocabulary</td>
<td></td>
<td>7</td>
</tr>
<tr>
<td></td>
<td><strong>NATIONAL STANDARDS</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td>S-Science, G-Geography, M-Math</td>
<td></td>
</tr>
<tr>
<td></td>
<td><em>SS-Social Studies, H-History</em></td>
<td></td>
</tr>
<tr>
<td>LESSON 1</td>
<td>Lunar Phases</td>
<td>9-19</td>
</tr>
<tr>
<td>Activity 1</td>
<td>Direction of Moons Orbit</td>
<td>10</td>
</tr>
<tr>
<td>Activity 2</td>
<td>Moon Rise Times</td>
<td>11</td>
</tr>
<tr>
<td>Activity 3</td>
<td>Solar Eclipse/New Moon</td>
<td>12-13</td>
</tr>
<tr>
<td>Activity 4</td>
<td>Reason for Moon Phases</td>
<td>14</td>
</tr>
<tr>
<td>Activity 5</td>
<td>First Quarter Moon</td>
<td>15</td>
</tr>
<tr>
<td>Activity 6</td>
<td>Waxing Gibbous Moon</td>
<td>15</td>
</tr>
<tr>
<td>Activity 7</td>
<td>Full Moon/Lunar Eclipse</td>
<td>16-17</td>
</tr>
<tr>
<td>Activity 8</td>
<td>Waning Gibbous/Third Quarter Phase</td>
<td>18</td>
</tr>
<tr>
<td>Activity 9</td>
<td>Waning Crescent Moon</td>
<td>19</td>
</tr>
<tr>
<td>LESSON 2</td>
<td>Moon Phase Times</td>
<td>20-22</td>
</tr>
<tr>
<td>LESSON 3</td>
<td>Earth Phases</td>
<td>23-25</td>
</tr>
<tr>
<td>Activity 1</td>
<td>Earth Phases/Moon Phases</td>
<td>23-24</td>
</tr>
<tr>
<td>Activity 2</td>
<td>Terminator (Sunrise/Sunset) on the Moon</td>
<td>25</td>
</tr>
<tr>
<td>LESSON 4</td>
<td>How Small Moon Covers A Large Sun</td>
<td>26</td>
</tr>
<tr>
<td>LESSON 5</td>
<td>Scale Models</td>
<td>27-29</td>
</tr>
<tr>
<td>Activity 1</td>
<td>Scale Model of the Earth &amp; Moon</td>
<td>27</td>
</tr>
<tr>
<td>Activity 2</td>
<td>Scale Model of Sun-Earth-Moon</td>
<td>28-29</td>
</tr>
<tr>
<td>LESSON 6</td>
<td>Moon’s Rotation</td>
<td>30</td>
</tr>
<tr>
<td>LESSON 7</td>
<td>Tides</td>
<td>31-34</td>
</tr>
<tr>
<td>LESSON 8</td>
<td>Lunar Formation</td>
<td>35-37</td>
</tr>
<tr>
<td>LESSON 9</td>
<td>Lunar Weather</td>
<td>38-39</td>
</tr>
<tr>
<td>LESSON 10</td>
<td>Moon Illusion</td>
<td>40</td>
</tr>
<tr>
<td>INFORMATION: Earth’s Nearest Neighbor</td>
<td>41-45</td>
<td></td>
</tr>
<tr>
<td>INFORMATION: Space Program</td>
<td>46-52</td>
<td></td>
</tr>
</tbody>
</table>
Vocabulary
For
"It's A Phase We're Going Through"

Blue Moon
A figure of speech that refers to four full Moons in a three month period or more commonly referred to as two full moons in one month.

Eclipse
Occurs when one object is blocked by another.
Lunar Eclipse
Occurs when the full Moon enters into the shadow of the Earth.
Solar Eclipse
Occurs when the new Moon crosses the face of the Sun.

Moon
An object that directly orbits a planet.

Moon Phases
Moon phases occur because of a changing angular separation between the Sun and Moon; do to the Moon orbiting the Earth; resulting in varying amounts of reflected moon light.

New Moon
When the Moon is aligned with the Sun, between the Sun and Earth. In the position it doesn’t reflect light back to the Earth.

Waxing
To grow larger through the diameter
First Quarter
When the Moon has moved 90 degrees from the sun forming a right angle with the Earth and Sun. Viewed at sunset it appears to be a half-moon with the right side lighted.

Full Moon
When the Moon is 180 degrees from the Sun. It appears to be completely lighted since it is opposite the sun.

Waning
To grow smaller through the diameter
Third Quarter
When the Moon has moved 270 degrees from the Sun forming a right angle with the Earth and Sun. Viewed at sunrise it appears to be a half-moon with the left side lighted.

Synchronous Rotation
The Moon rotates once in one revolution of the Earth. Because of this, one side of the Moon always faces the Earth.

Terminator
The line that divides daytime from nighttime; thus, the terminator represents the location of either sunrise or sunset. Along the terminator the shadows are the longest thus producing a 3D affect. This allows one to see mountain ranges and craters in three dimensions.

Tides
Caused by a gravitational attraction between two bodies. The Moons gravity causes two high tides and two low tides or four changes in the shoreline on the Earth everyday.

Neap Tides
Occur when the Moon is at first or third quarter phase. This produces the smallest difference between high tide and low tide.

Spring Tides
Occur when the Moon is aligned with the Earth and Sun either at new moon or full moon producing the highest high tides and the lowest low tides.
LESSON 1: Lunar Phases

OBJECTIVE

At the end of this lesson the student should be able to demonstrate and explain lunar phases and eclipses.

NOTE TO THE TEACHER

This lesson looks very lengthy and involved. Once you rehearse it a few times it is simple to do. Computers are supposed to be simple as well, and yet I occasionally get hung up on some “simple” step. So, if you run into a problem don’t hesitate to email me (aklinger@phm.k12.in.us) or call me 258-9569. I won’t make fun of your question if you promise not to make fun of my computer questions.

MATERIALS

1. 8 styrofoam balls minimum 3” in diameter
2. 1 light source with a 60 or 75 watt bulb
3. 1 table or stand for light source

PROCEDURE

Select 8 students and hand each a ball. Have each of them take out a pencil (at least 6” in length) or pen and gently insert it half way into the ball. Position the 8 students equally around the light source. Turn on the light source and darken the room.

Explain that the ball represents the Moon, the light source is the Sun and their head is the Earth. The Moon should be held approximately 10” from the face. If held at a greater distance the Moons’ reflected light would be distorted such that a First Quarter Moon will look like a Waxing Gibbous Moon.
ACTIVITY 1: Direction of Moon's Orbit

OBJECTIVE

At the end of this activity the student should be able to demonstrate and explain how the counterclockwise orbit of the Moon around the Earth translates into a west to east motion as viewed from the Earth. Therefore, the Moon will always be further (12°) to the East when viewed at the same time every day or night.

INFORMATION

The Moon’s orbit is from west to east as viewed from the Earth approximately 12° per day; or, counterclockwise around the Earth 12° per day as viewed from the North Star.

Earth View

- E - W
  Day 5 Day 4 Day 3 Day 2 Day 1

North Star View

Moon

STUDENT DEMONSTRATION

The student's left shoulder is east and their right shoulder is west. Their nose is south. Have the students move the Moon (keeping it at eye level) from their right (west) slowly to their left (east). The emphasis should be that the Moon will always be a little bit (12°) further to the east when viewed at the same time every night.

INTERPRETATION

ASK THEM: “If the Moon is directly south at 6pm tonight, where will it be tomorrow at 6pm?”

ANS: Slightly (12°) left (east) of south; in other words, slightly southeast.
ACTIVITY 2: Moon Rise Times

INFORMATION

The Earth rotates once in 24 hours. That means in every hour the Earth rotates $15^\circ$. ($360^\circ$ divided by 24 hrs = $15^\circ$ per hour). Sixty minutes divided by $15^\circ$ = $1^\circ$ per 4 minutes. In one day the Moon will move $12^\circ$ per day from west to east.

INTERPRETATION

1. If the Moon is directly south at 6 pm tonight, what time will it be directly south tomorrow night? In 24 hours the Moon will have moved $12^\circ$ to the east. In order for the Earth's rotation to catch up with the Moon it must rotate an additional $12^\circ$. We know that $1^\circ$ of Earth motion equals 4 minutes of time. Therefore $12^\circ \times 4$ minutes = 48 minutes. In reality because of the changing tilt of the Earth (relative to the Sun and the Moon) as it revolves around the Sun the angle of Moonrise will vary from month to month. The average time used is 50 minutes instead of 48 minutes. You must add the 50 (48) minutes since the Earth has to catch up with the Moon in order for the Moon to once again be directly south.
   ANS: 6:50pm

2. If the Moon rises at 8 pm tonight, what time will it rise tomorrow night?
   ANS: 8:50pm

3. If the Moon rises at 8 pm tonight, what time will it rise three nights from now?
   ANS: 10:30pm

4. If the Moon sets at 6am in the morning what time will it set three mornings from now?
   ANS: 8:30 am
ACTIVITY 3: Solar Eclipse/New Moon/Dark Side of Moon

STUDENT DEMONSTRATION/INTERPRETATION/INFORMATION

Each student in the group should place the Moon between their eyes and the light source at a distance of 10.”

ASK THEM: “Can you see the Sun?” “Why?”
ANS: No, because the Moon is blocking the Sun’s light.

“This is called a Solar Eclipse which means the Moon is blocking out the sun’s light. The only time a Solar Eclipse can occur is when the Moon is new and is located directly between the Earth and the sun.”

ASK THEM: “Is the side of the Moon facing you lit up or totally dark?” ANS: Totally dark

“The side of the Moon facing you is totally dark because it is not reflecting any sunlight to you. This is called a New Moon”.

Have them hold the moon so that it is directly above the light source. “The Moon is still new. We can’t see if from the Earth because it is not reflecting any light.” Some student might ask: “Why then isn’t there a black spot in the sky when the new Moon is above the Sun.” The reason is, in reality the Moon only takes up .5 degrees of sky space; thus it is a tiny dot, which if you’ll remember, is not reflecting any light. Point out to them that the new Moon could also be below the Sun as well.

ASK THEM: “Do we have a Solar Eclipse every month?”
ANS: No. The New Moon is usually above or below the Sun. At least twice a year the New Moon will align with the sun producing a Solar Eclipse somewhere on the day side of Earth.

ASK THEM: “Will everyone on the day side of the Earth see a Solar Eclipse, why or why not?”
ANS: No. Only a small portion of Earth will see the Solar Eclipse because the Moon being very small will cast a small show onto the Earth; therefore, only those folks located in the shadow path will see a Solar Eclipse.

ASK THEM: “Why does the New Moon sometimes: above, below, or crosses the face of the Sun?”
ANS: The Moon’s orbit is slightly tilted and it wobbles very slowly as it goes around the Earth.
DEMONSTRATION

Wobble of Moon's Orbit

Take a quarter or half dollar place it on its edge and give it a spin. Explain to the students that the edge of the quarter represents the orbit of the Moon around the Earth. As the spinning quarter slows down it begins to undulate or wobble. The Moon's orbit acts in a similar fashion though the Moon's wobbly orbit is nowhere near the same as the wobbling quarter. A complete wobble of the Moon's orbit where an undulation comes back to the near the same spot takes about 18.9 years. This 18.9 year cycle is called the Saros Cycle.

ASK THEM: “Why do you think the Moon’s orbit wobbles?”
ANS: The combined gravitational pull of the Sun and Earth on the Moon cause the Lunar orbit to wobble.

STUDENT DEMONSTRATION

Have the students position the Moon just to the right of the Sun. Have them move the Moon across the Sun from right to left.

ASK THEM: “What side of the Sun does the New Moon enter during a Solar Eclipse?”
ANS: The New Moon enters the sun's right (west) side during a Solar Eclipse.
ACTIVITY 4  Reason for Moon Phases

PROCEDURE/INTERPRETATION

Have the students start at the New Moon phase. Remind them to keep the Moon 10" from their face. Tell them to move the Moon slowly to their left in a path level with the Sun.

ASK THEM: "What are you noticing about the Moon since it left the New Moon position?"
ANS: As it moves from the New Moon position it is reflecting more and more of the Sun's light back to you (Earth) in the form of a growing crescent shape. The growing crescent shape is called "waxing."

ASK THEM: "What is causing this crescent shape to grow?"
ANS: The increasing angular separation between the Sun and Moon.

INFORMATION  Reasons for the Lunar Phases

Lunar phases are the result of the changing ANGULAR SEPARATION between the Sun and Moon caused by the MOON ORBITING THE EARTH, resulting in VARYING AMOUNTS OF REFLECTED MOONLIGHT (actually sunlight) back to the Earth
NOTE: This concept needs to be repeated several times. It is the key to understanding lunar phases.
**ACTIVITY 5:** First Quarter Moon (Half Moon)

**PROCEDURE/INTERPRETATION**

Have the students move the Moon to their left so that it forms a 90° angle to the Sun. It is important to keep the Moon within 10" of their face; otherwise, it will look more like a waxing gibbous moon than a "half moon." The students should turn so that their right shoulder points to the Sun. Their right shoulder represents west. Therefore, it is now evening time with the Sun to their right and the First Quarter Moon directly south.

It is very important to mention that it takes about 7.5 days for the Moon to go from New Moon to First Quarter.

**ASK THEM:** “Why do we call it a first quarter Moon when it looks like half a Moon?”

**ANS:** Because the Moon is one-fourth of the way around the Earth.

![Diagram of First Quarter Moon]

**ACTIVITY 6:** Waxing Gibbous Moon

**PROCEDURE/INTERPRETATION**

Have the students move the Moon slightly left of First Quarter.

**ASK THEM:** “Are you seeing more or less reflected moonlight? Why?”

**ANS:** More, because the angular separation continues to grow between the Sun and the Moon.

![Diagram of Waxing Gibbous Moon]
**ACTIVITY 7: Full Moon/Lunar Eclipse**

**PROCEDURE/INTERPRETATION**

The students should continue moving the Moon until it is opposite the Sun. The Moon is now aligned with the students left (east shoulder), while the Sun is still aligned with the right shoulder. The Moon is now opposite the Sun.

*ASK THEM:* “What is the angular separation between the Moon and the Sun?”  
ANS: 180°

![Diagram showing the positions of the Sun, Earth, and Moon]

*ASK THEM:* “How many days did it take for the Moon to move from First Quarter Phase to Full Phase?”  
ANS: Approximately 7.5 days

*ASK THEM:* “What phase of the Moon will always rise when the Sun sets?”  
ANS: Full Moon

*ASK THEM:* “What happened to the Moon when it was moved opposite the Sun?”  
ANS: The Moon was eclipsed by the Earth’s (students head) shadow.

*ASK THEM:* “Which side of the Moon received the Earth’s shadow first?”  
ANS: For this answer they need to slowly repeat moving the Moon into the Earth’s shadow. They’ll see the Earth’s shadow begins on the Moon’s left (east) side.

*ASK THEM:* “When the full Moon enters into the Earth’s shadow what kind of an eclipse occurs?”  
ANS: Lunar Eclipse

Have the students move the full Moon so that it is above the shadow of the students head. Explain that a full Moon is usually above or below the earth’s shadow. However, a couple of times a year the full Moon will move into the Earth’s shadow, thus producing a LUNAR ECLIPSE.
With the full Moon positioned above the shadow of the students head have the students turn so that their back is to the Sun. In this position it is now midnight and the full Moon is directly south

**ASK THEM:** “Which takes longer a Solar Eclipse or a Lunar Eclipse? Why?”

**ANS:** Lunar Eclipse because the Moon which is one-fourth the size of the Earth, passes into the shadow of the Earth which is four times bigger than the Moon. A total Lunar Eclipse can last up to three hours. The Moon casts a very small shadow onto a much larger Earth. Therefore, a Solar Eclipse lasts only a few minutes.

**ASK THEM:** “Does everyone on the dayside of the Earth see a Solar Eclipse?” Does everyone on the night side see a Lunar Eclipse?”

**ANS:** During a Solar Eclipse only a tiny portion of the Earth receives the Moon’s shadow. During a Lunar Eclipse everyone in the same hemisphere will see the eclipse.
**ACTIVITY 8: ** Waning Gibbous to Third Quarter

**PROCEDURE**

While keeping the Moon at the full Moon phase have the students turn to their left (east) so that their shoulders aligns with the Sun.

**ASK THEM:** “What time of day is it when the left (east) shoulder aligns with the Sun?”
**ANS:** Morning (Sunrise)

**ASK THEM:** “What phase of the Moon always sets (west) as the Sun rises (east)?”
**ANS:** Full Moon

With the full Moon to their right (west) have the students slowly bring the Moon around so that it is directly south.

**ASK THEM:** “Is the Moon phase growing thicker or thinner? Why?”
**ANS:** Thinner. This is called “waning.” The waning phase occurs because the angular separation is growing less as the Moon moves toward the Sun.

**ASK THEM:** “In the morning when the Moon is directly south it is called a Third Quarter Moon even though it looks like a half moon why do we call it a Third Quarter Moon?”
**ANS:** Because the Moon is three-fourths of the way around the Earth.

**ASK THEM:** “What is the angular separation between the Sun and the Moon when the Moon is in the Third Quarter Phase?”
**ANS:** 90°

**ASK THEM:** “How many days does it take to go from the Full Moon Phase to the Third Quarter phase?”
**ANS:** Approximately 7.5 Days
ACTIVITY 9: Waning Crescent Moon/Blue Moon

PROCEDURE/INTERPRETATION

The students should slowly move the Moon from the Third Quarter Phase to the New Phase.

**ASK THEM:** “Describe what you’re seeing in regards to the amount of reflected light coming back to them from the Moon.”
**ANS:** The amount of reflected light from the Moon decreases as the Moon approaches the new phase. Thus, the crescent shape grows thinner.

**ASK THEM:** “Is the angular separation growing more or less as the Moon approaches the Sun?”
**ANS:** Less

**ASK THEM:** “Approximately how many days have elapsed from the Third Quarter Phase to the New Phase?”
**ANS:** Approximately 7.5 days

**ASK THEM:** “Approximately how many days does it take the Moon to orbit the Earth?”
**ANS:** Approximately 30 days

**ASK THEM:** Is it possible to have two Full Moons in one month?
**ANS:** Yes, provided the month has 31 days.

INFORMATION Blue Moon

Many people think a “Blue Moon” occurs when there are two Full Moons in one month. Actually, the term “Blue Moon” means four Full Moons in a three month period. Where the term “blue” comes from is anyone’s guess.
LESSON 2: Moon Phase Times

MATERIALS
2 3"x5" index cards
1 large marker
1 light source (60 or 75 watt bulb)
1 styro foam ball (Moon)
2 students

PROCEDURE/INTERPRETATION
Mark one index card with a large letter “E” and mark the other card with a large letter “W.” Select a student to represent the Earth. Place the “E” card in the students left hand, and place the “W” card in the students right hand. Turn on the light source and darken the room. Have the student face the light source and raise both arms to shoulder level. The left arm is east, the right arm is west and their nose represents the direction of south. The student is currently in the noon position since the sun is directly south (in line with their nose).

The second student will take the moon (placed on a pencil) and move it from the New Moon position to the First Quarter phase.

ASK THEM: “The Earth is in the Noon position. What direction is the First Quarter Moon?”
ANS: East (Diagram A)

ASK THEM: “What time will the First Quarter Moon always rise?”
ANS: Noon

The “Earth” should rotate until the student’s nose aligns with the First quarter Moon.

ASK THEM: “In this position what direction is the Fist Quarter Moon?”
ANS: South (Diagram B)

ASK THEM: “What direction is the Sun?”
ANS: West

ASK THEM: “What direction will the First Quarter always be at sunset?”
ANS: South

The “Earth” should rotate until the students right should aligns with the First Quarter Moon.

ASK THEM: What time will the First Quarter Moon always set?”
ANS: Midnight (Diagram C)
The “Earth” should rotate until the left shoulder aligns with the Sun, that is, the “E” card aligns with the light source. This represents sunrise.

**ASK THEM:** “Is the First Quarter Moon visible at sunrise?”
**ANS:** Definitely not

The “Earth” should now face the Sun. Once again this represents the noon position. The student with the Moon should move to the Full Moon position. Remind the class for this to happen the Earth would have made approximately seven complete rotations (days).

**ASK THEM:** “I want you to predict the time when the Full Moon will: rise, be directly south, and set.”

“Let’s see if your predictions are correct.” Have the “Earth” raise both arms from their sides with the “E” card in the left hand and the “W” card is in the right hand. The “Earth” should rotate until the left arm aligns with the Full Moon.

**ASK THEM:** “What time will the Full Moon always rise?”
**ANS:** Sunset (Diagram D)

**ASK THEM:** “What will always set at the Full Moon rises?”
**ANS:** Sun

Have the “Earth” rotate until the student’s nose aligns with the Full Moon.

**ASK THEM:** What time will the Full Moon always be south?”
**ANS:** Midnight. Note the student’s back is to the Sun (Diagram E)

The “Earth” should now rotate until the students right “W” arm aligns with the Full Moon.

**ASK THEM:** What time will the Full Moon always set?”
**ANS:** Sunrise (Diagram F)

**ASK THEM:** “What will always rise as the Full Moon sets?”
**ANS:** Sun

---

Diagram D  

Diagram E  

Diagram F)

![Diagram](image-url)
The student with the Moon should move it to the Third Quarter phase. Remind them that another seven days have passed.

**ASK THEM:** “I want you to predict the time when the Third Quarter Moon will: rise, be directly south, and set.”

“Let’s see if your predictions are correct.” Have the “Earth” raise both arms from their sides with the “E” card is in the left hand and the “W” card is in the right hand. The “Earth” should rotate until the left arm aligns with the Third Quarter Moon.

**ASK THEM:** “What time will the Third Quarter Moon always rise?”

**ANS:** Midnight (Diagram G)

Have the “Earth” rotate until the student’s nose aligns with the Third Quarter Moon.

**ASK THEM:** What time will the Third Quarter Moon always be south?”

**ANS:** Sunrise (Diagram H)

The “Earth” should now rotate until the students right “W” arm aligns with the Third Quarter Moon.

**ASK THEM:** What time will the Third Quarter Moon always set?”

**ANS:** Noon (Diagram I)

---

**Diagram G**

![Diagram G](image)

**Diagram H**

![Diagram H](image)

**Diagram I**

![Diagram I](image)
LESSON 3: Earth Phases

ACTIVITY 1: Earth Phases/Moon Phases

MATERIALS

Light Source 60 or 75 watt bulb
Table for light source
Table for Earth
2 Styrofoam balls
Dowel rod 2' in length or equivalent
A 2" square of modeling clay or equivalent

PROCEDURE/INTERPRETATION

Place one end of the dowel rod into the Styrofoam ball and place the other end in the square of clay. The ball at the end of the dowel rod will represent the Earth. Place this on a table approximately 5 feet from the light source. Turn on the light source and darken the room.

Select a student and have this student place a pencil into the other Styrofoam ball. This will represent the Moon. Have the student hold the Moon in the New Moon position. Check the diagrams at the end of this activity.

ASK THEM: “From the Earth what phase is the Moon?”
ANS: New

ASK THEM: “What phase is the Earth as viewed from the Moon?”
ANS: Full

Have the “Moon” move to the waxing crescent phase halfway between New Phase and First Quarter.

ASK THEM: “From the Earth what phase is the Moon?”
ANS: Waxing Crescent

ASK THEM: “What phase is the Earth as viewed from the Moon?”
ANS: Waning Gibbous

The “Moon” should now move to the First Quarter position.
ASK THEM: “From the Earth what phase is the Moon?”
ANS: First Quarter

ASK THEM: “What phase is the Earth as viewed from the Moon?”
ANS: Third Quarter

The “Moon” should now move to the waxing gibbous phase.
ASK THEM: “From the Earth what phase is the Moon?”
ANS: Waxing Gibbous

ASK THEM: “What phase is the Earth as viewed from the Moon?”
ANS: Waning Crescent

The “Moon” should now move to the Full Moon position.

ASK THEM: “From the Earth what phase is the Moon?”
ANS: Full

ASK THEM: “What phase is the Earth as viewed from the Moon?”
ANS: New

ASK THEM: “What conclusion can you make about Earth phases relative to Moon phases?”
ANS: They are opposite

**Diagrams for the Moon Earth phases/positions**

```
<table>
<thead>
<tr>
<th></th>
<th>Full Earth Earth</th>
<th>Waning Gibbous Earth</th>
<th>Third Quarter Earth</th>
<th>Waning Crescent Earth</th>
<th>New Earth</th>
</tr>
</thead>
<tbody>
<tr>
<td>New Moon</td>
<td>Waxing Crescent Moon</td>
<td>First Quarter Moon</td>
<td>Waxing Gibbous Moon</td>
<td>Full Moon</td>
<td></td>
</tr>
</tbody>
</table>

Have all the students in the class, one by one, line up at the New Moon position (actually stand behind the light source) and walk around the Earth noting how the Earth goes thru phases.
ACTIVITY 2: Terminator (Sunrise/Sunset on the Moon)

MATERIALS
Make a copy of the following diagram and have the students answer the following questions.

![Diagram of Earth and Moon with points X, Z, and N, U, S]

INTERPRETATIONS

1. What is the phase of the Earth as viewed from the Moon?
   ANS: Third Quarter

2. What time is it a position “X”? A. Noon B. 6pm C. midnight D. 6am
   ANS: B

3. Is the sun rising or setting for people at position “X”?
   ANS: Setting

4. What phase is the Moon as viewed from the Earth?
   ANS: First Quarter

5. Is the Sun rising or setting at position “Z”?
   ANS: Rising

6. The line that separates daylight from darkness is called the terminator. At the terminator would you expect the shadows to be long or short?
   ANS: Long

If you have a telescope use it to look along the terminator of the Moon. Waxing Crescent and First Quarter phases are excellent times to look. Along the terminator the shadows are long producing a three dimensional appearance. Thus, with a telescope you can see down into the craters of the Moon and/or see the mountains sticking up from the surface. If you have a high-powered eyepiece you will actually feel like you are flying over the surface of the Moon. The motion you are witnessing is the rotation of the Earth!
LESSON 4: How a Small Moon Covers up a Very Large Sun

INFORMATION/INTERPRETATION

How can a very large Sun be completely covered up by a very small Moon during a Total Solar Eclipse? Why does a Full Moon appear to have the same size as the Sun?

The Moon's diameter is 3,476 km. The Sun's diameter is 1,400,000 km

1. How many times bigger is the Sun's diameter?
   ANS: 403

   The Moon is 376,800 km from the Earth. The Sun is 150,000,000 km from the Earth.

2. The Sun is how many times farther away from the Earth than the Moon?
   ANS: 391

   The Earth's diameter is 12,900 km.

3. How many times the Earth's diameter is the Sun away from the Earth?
   ANS: 108

4. How many times the Moon's diameter is the Moon away from the Earth?
   ANS: 108

   The Sun is approximately 400 times the diameter of the Moon and it is also about 400 times as far away from the Earth as is the Moon. Also, both the Sun and the Moon are just about 108 times their own diameters away from Earth. Thus, we can conclude that any round object like a dime or a beach ball, when held about 108 times it's own diameter away from the eye, will have the same apparent diameter as the Sun or the full Moon.

5. How far away would you have to hold a penny so that it appears to have the same size as a Full Moon or the Sun? A penny has a diameter of 2 cm.
   ANS: 2 cm x 108 = 216 cm or 2.16 m (That’s the distance of 2 meter sticks)
LESSON 5: Scale Model of the Earth Moon

ACTIVITY 1: Earth Moon Scale Model

MATERIALS

One meter stick per two student
Two sheets of construction paper, one blue, one white
Drawing compass
Scissors
Magic Marker (Black or Blue)

INFORMATION

For this investigation the Moon will have a diameter of 3,476 km, Earth 12,900 km
The distance between the Earth and the Moon is 376,800 km
The scale for this investigation will be 2.5 cm = 1,738 km

INTERPRETATION

1. In scale, how many cm represents the diameter of the Moon?
   ANS: 5cm

2. In scale how many cm represents the diameter of the Earth?
   ANS: 18.6cm

3. In scale, how many cm represents the distance separating the Earth and the Moon?
   ANS: 542 cm

4. In scale how many meters separates the Earth and the Moon?
   ANS: 5.42 M

PROCEDURE

Have the students draw, using a drawing compass, the Moon on the white paper; and, the Earth on the blue paper using the scale diameters they obtained in their interpretations. Label the blue circle “Earth,” and the white circle “Moon.” Select a blue Earth and a white Moon and place them on the front wall using the scale distance obtained in the interpretations.

INFORMATION       Going to the Moon

Using this scale you can’t place the Sun or the Sun’s distance in the front of the room. However, you can pint out that American Astronauts flew to the Moon between 1968 and 1972. During this time 12 Astronauts walked on the Moon and came back safely to the Earth. Hopefully the students will have a sense of the distance they traveled.
ACTIVITY 2: Sun/Earth/Moon Scale Model

MATERIALS

One meter stick per two student
One sheet of yellow construction paper
Drawing compass
Scissors
Magic Marker (Black or Blue)
Straight pin with a tiny blue sphere on top
Straight pin with a tiny white sphere on top

INFORMATION

For this investigation the Moon will have a diameter of 3,476 km; Earth 12,900 km
The distance between the Earth and the Moon is 376,800 km
The Sun is 150,000,000 km from the Earth. The Sun’s diameter is 1,400,000 km
The scale for this investigation will be 2.5 cm = 1,738 km

The Sun's diameter is: 1,400,000 km
The Earth's diameter is: 12,900 km
The Moon's diameter is: 3,225 km
The distance between the Earth and Sun is: 150,000,000 km
The distance between the Earth and the Moon is: 376,800 km
Venus’s diameter is 12,625 km
Venus's distance is 105,000,000 km
Mercury’s diameter is 4,630 km
Mercury's distance is 60,000,000 km
The scale for this model will be 1 cm = 93333 km

INTERPRETATION

1. In our Sun/Earth/Moon Scale Model what is the scale diameter size of the Sun?
   ANS: 15 cm

2. What is the scale diameter of the Earth? Answer in mm's.
   ANS: 1.4 mm

3. What is the scale distance separating the Sun and the Earth?
   ANS: 16.07 M

4. What is the scale diameter of the Moon? HINT: Keep in mind the Moon’s diameter is 1/4 the diameter of the Earth.
   ANS: .35 mm (1/3 of a mm)

5. What is the scale distance separating the Earth and the Moon?
   ANS: 4 cm
6. What is the scale diameter of Venus?
   ANS: 1.35mm (Nearly the same size as the Earth)

7. What is the scale distance between the Sun and Venus? Answer in Meters
   ANS: 11.25 M

8. What is the scale diameter of Mercury? Answer in mm's.
   ANS: .5 mm

9. What is the scale distance between the Sun and Mercury? Answer in Meters
   ANS: 6.43 M

PROCEDURE

Have the students cut out the 15 cm diameter Sun. Select one of the Suns and tape it at the front of your room at the corner of a very long side wall 17 M or 50' in length. You may have to use a hallway.

Show the students the straight pin with the tiny blue sphere on top and explain this represents the scale size of the Earth. Measure 16 meters from the scale model of the Sun and hold up the scale model of the Earth. Emphasize this is the actual scale model of the Sun and Earth both in distance and size.

Further explain the Moon would be 1/4 the size of the blue sphere located 4 cm from the Earth.

Plot in the location of Venus and Mercury. Use the white straight pin and tape it to the wall at the appropriate distance from the Sun. You could use a small piece of paper with a tiny pencil dot to represent Mercury and tape it at the appropriate distance from the Sun.

CONCLUSIONS

A. There is a lot of empty space between the Sun and the Earth
B. For its size and distance the Sun, which is a star, puts out a lot of heat and light energy.
C. It is easy to see how a New Moon can be above or below the Sun. It is also easy to see how a Full Moon can be above or below the Earth’s shadow.
D. It is easy to see how the Moon’s orbital wobble is actually very slight
LESSON 6: Moon Rotation

INFORMATION
Synchronous Rotation

One side of the Moon always faces the Earth. From the Earth we can't see the backside of the Moon. The only humans to see the backside of the Moon are the American Astronauts who orbited and landed on the Moon between 1968 and 1972. Many believe since we can see only one side of the Moon that it doesn't rotate. However, that is not the case. The Moon rotates once in every revolution around the Earth. You can easily demonstrate this concept.

PROCEDURE
Find a large book with a very colorful cover. Stand in front of your class with the cover of the book toward them. Explain to your students that only one side of the Moon faces the Earth. From the Earth we never see the backside of the Moon.

Tell them to keep their eyes on the cover of the book because you're about to perform magic and you don't want them to miss a thing. Move all the way around the class keeping the cover toward them. When you get back to your starting point ask them: "Did I turn the book while I walked around you?" Most likely they'll say: "No! You didn't turn the book. Do this orbit at least two more times asking them each time: Am I turning the book?"

Explain how the cover of the book is parallel to the front wall of your classroom. The front wall of your room could also represent the sun and your position (A) would be the New Moon phase. When you get to Position C in the bottom diagram ask them is the cover still parallel to the front of the room or is it now perpendicular to the front of the room. They will see that the book is now perpendicular to the front of the room. In order for this to happen you had to slowly turn the book as you walked to position C.

Move to position E, which would be the Full Moon phase. The same side of the Moon is still facing them. In order for this to happen the Moon had to rotate 180°. The Moon is also 180° from the starting point (New Moon). Thus, the Moon has made one-half turn, in one-half orbit. Move to position G keeping the cover of the book toward the class. Now move back to the starting point Position A. You've now made one complete orbit of the class; and, the Moon has made one full rotation on its axis with the same side always pointing toward the class.

Position E
Position F
Position G
Position H

Position D
Class
Position C
Position B

INTERPRETATION
: The Moon once rotated at a much faster rate. Why has it slowed down?
ANS: Earth's Gravity, which is also called a "Tidal Force."
LESSON 7: Tides

INFORMATION TIDES

A. When two spherical bodies are close to each other, each exerts a gravitational pull on the other. The tidal force on Earth from the Moon is due to the fact that gravity gets weaker with distance. This side of Earth nearer to the Moon gets pulled stronger than the far side, so Earth feels a stretch, making the planet somewhat oblong (football-shaped). Therefore, the side of the Moon facing the Earth feels a stronger pull on it than the far side. However, this oblateness is so slight that an observer on Earth wouldn't notice it. The Earth's surface will also bulge about 30 centimeters (one foot) do to the pull of the Moon.

B. Tides are the result of the gravitational pull of the Moon creating a bulge of water near the imaginary line of the pull. The Sun also has a gravitational pull on the water, but not nearly as great or noticeable as the Moon's. The Sun accounts for one-third of the tides on Earth.

INFORMATION SPRING TIDES

Spring Tides occur only during the full phase and new phase of the Moon. Since we note each of these phases during a month, we can conclude that there are two spring tides a month. These tides will last about one to three days with two high tides and two low tides occurring almost at the same location in a little over 24 hours. Spring Tides have the greatest difference between high and low tide. Thus, the highest high tides and the lowest low tides occur during new and full Moon.

14-15 days later...

14-15 days later...
INFORMATION

NEAP TIDES

Neap Tides occur during the first and third quarter phases of the Moon when the Moon is at right angles to the Earth and the Sun. Here we have the least difference between high tide and low tide because the solar tide partially cancels the lunar tide.

\[
\begin{array}{c}
\text{HIGH} \\
\text{LOW} \\
\text{HIGH}
\end{array}
\]

First Quarter

INFORMATION

High Tides

High tides occur twice a day. There is a high tide on the side of the Earth nearest the Moon and a high tide on the side of the Earth away from the Moon. (The water at high tide can rise as much as fifty feet.) The tide nearest the Moon is caused by the gravitational pull of the Moon. The high tide on the other side of the Earth is caused by the fact that the center of the Earth feels a greater force toward the Moon than water on that side so the main body of the Earth is pulled away from that water, making another high tide on the side opposite the Earth.

INFORMATION

Low Tides

The differential gravitational pull on the various parts of the Earth results in two locations of the Earth having high tides. The water that went into making the high tides has been pulled away from other parts of the Earth and so a low tide lies midway between the areas of high tide. Thus, two low tides and two high tides during the course of a day.

The actual tidal phenomenon is much more complicated than what has been described. We must consider that the Earth is rotating and its landmasses disturb the flow of water. The interplay between the shape of the shoreline, the depth of the water, latitude on the Earth and the location of the Moon (seasons) all play a part in determining exactly when and where; and how high and low high and low tides will be.

The Sun also contributes to the tides, but only half as much as the Moon does because of its much greater distance, despite its larger mass. However, in most cases the Sun's tides are not noticed because of the Moon's tides. During the Moon's new and full phases the Sun's gravity adds to the tides. On the other hand, when the Sun's tides are opposite the Moon's (quarter phases), they tend to diminish the Moon's and this causes the change from low to high tide to be less than normal.
Tides also occur on dry land. The surface of the Earth actually stretches to allow for a rising and falling action. The maximum dry-land tide is about 23 cm (9 in). That is, the surface is about 23 cm further from the center of the Earth at high tide compared to low tide.

**INTERPRETATION**

1. How many high tides occur everyday?  
   **ANS:** 2

2. How many low tides occur everyday?  
   **ANS:** 2

3. How many changes in shoreline occur everyday?  
   **ANS:** 4

4. When the Moon is on or near the horizon are you experiencing high tide or low tide?  
   **ANS:** Low Tide

5. When the Moon is at its highest point in the sky are you experiencing high tide or low tide?  
   **ANS:** High Tide

6. How many hours separates high tide from low tide?  
   **ANS:** Approximately 6 hrs. Actually its closer to 5 hrs. 50 minutes.

7. If Low Tide occurs at Noon today what time will occur tomorrow?  
   **ANS:** 1pm (Actually, its 12:50pm)

**TIDAL FRICTION**

A. The Earth’s gravitational pull on the Moon causes an elongation in the Moon’s shape. When this bulge developed long ago it caused the Moon to slow down its rotation. It became so slow that the bulge now points almost directly toward the imaginary line of gravitational pull from the Earth. Therefore, we can conclude that the Moon had a faster rotation billions of years ago.

B. The land masses and surrounding oceans interact such that if the land masses exert a force on the tidal bulges as the Earth turns, it follows from Newton’s Third Law that the bulges exert an equal and opposite force on the Earth. The result: *The Earth’s rotation is slowing down by*:

- .00002 seconds per year
- .002 seconds per 100 years
- 2.000 seconds per 100,000 years
- 20. seconds per 1,000,000 years
Since the birth of Christ, the period of Earth's rotation has decreased by .02 seconds. We believe that billions of years ago, the Earth may have rotated once in 6 hours! It is possible that millions of years from now the Earth and the Moon will be in synchronous rotation.

C. The tides are causing the Moon to spiral away from us at a rate of 2 inches per year. Initially, the Moon may have been at a distance of 14,000 miles. Within a few hundred million years of its birth, the Moon moved to half its present distance. To understand why the Moon is receding from us, imagine for a moment that neither Earth nor Moon rotated and that the Sun's tidal effect could be ignored. In this case, one of the two high ocean tides would be directly between the Earth and Moon, while the other would be on the opposite side of Earth from the Moon.

Now add back the Earth's rotation. Earth rotates in the same direction that the Moon orbits, but Earth spins much faster (once a day) than the Moon goes around it (once every 29 days). The rapid rotation causes the high tide to be pulled slightly ahead of the Moon. This tide gives Earth a handle to crank up the Moon's orbit. The high tide pulls the Moon forward in its orbit, causing the Moon to accelerate and, therefore, to spiral away. In other words, the Moon is steadily moving up and up.

As anyone who climbs long flights of stars knows, it takes energy to move up. The energy that drives the Moon away comes from the rotating Earth. It's called angular momentum. The total angular momentum in the Earth-Moon system, which is related to the energy stored in both rotation and revolution, must remain the same. Since the Moon is gaining angular momentum as it spirals away, Earth must lose the same amount of angular momentum.

Earth loses angular momentum because the high tide closest to the Moon is trying to get back directly underneath the Moon, while the high tide farthest from the Moon is trying to get as far away from the Moon as possible. Consequently, the high tides flow westward, and in so doing, they encounter continents and islands. The water pushes against the land masses, which, because of rotation, are moving eastward. The net result is that the westward motion of the tides retards the eastward rotation; thus, slowing down the rotation.

Since the Moon is moving away, it must once have been closer to the Earth. The closest the Moon could have been was about 11,775 km (7,300 miles) or 1/20th its present distance. If it had been any closer, the tides created on it by Earth would have ripped the Moon apart, turning it into a ring.

D. Let's suppose in the beginning the Moon formed 10 times closer to us than it is today. In this case, the tides on the young Earth were 1,000 times higher than they are today, since tidal forces vary inversely with the cube of the distance. These enormous tides would have plunged miles inland and withdrew every three hours (remember, the day was only six hours long). As they moved over the land, the incredible volumes of water scraped and pounded the primeval rock, removing and pulverizing a considerable amount of it. Every time the tide retreated, it dragged this material back into the ocean. Continually churned up in the water, these chemicals formed the "broth" in which life probably formed.
Both diagrams represent an astronaut's view of ocean tides. This of course is an exaggerated view of the tides as you might see them if you could fly high enough above the Earth and Moon. The imbalanced gravitational pull of the Moon causes the oceans to be slightly non-spherical, creating two high tides and two low tides. Of course, the actual tides would be much smaller than shown in these two diagrams.

**DIAGRAM A**

**Diagram A** represents an Earth that doesn't rotate. In this case, the two high tides would lie on a straight line from the center of the Moon to the center of the Earth. Thus, the gravitational force would be directly from the center of the Moon to the center of Earth.

**DIAGRAM B**

Now take a look at what happens on the rotating Earth. Because Earth rotates faster (once every 24 hours) than the Moon revolves (once every 29 days), the high tides are not aligned as in **Diagram A**. Instead, the rotation pulls the tides around, so that the high tide closest to the Moon outpaces the Moon. This nearer tide exerts a gravitational force on the Moon causing the Moon to spiral outward. In return, the Moon exerts a gravitational force on the high tide, causing the Earth to rotate slower.
LESSON 8: Lunar Formation

INFORMATION  FORMATION OF THE MOON  (Collision Theory)

4.6 Billion Years Ago (Formation of the Moon)
1. Scientists and astronomers believe the Moon, like the Earth, formed about 4.6 billion years ago. Evidence indicates that the Moon comes from the Earth, but not the Pacific Ocean as some scientists, a long time ago, thought. Instead, a celestial object with a mass at least twice that of Mars struck the newly formed Earth with a glancing blow between 50 and 90 million years after the formation of the Solar System. In a matter of minutes this titanic collision jettisoned molten and vaporized rock from the Earth's newly formed mantle and crust as well as from the impactors mantle and crust. The core of the impacting source probably became part of the of the Earth's core. Much of this material escaped into the solar system or fell back onto the Earth. The residue, however, went into orbit and coalesced (came together) to form the Moon. Since the core's are primarily iron this explains the lack of iron on the Moon.

The Moon has much less iron than does Earth, as evidenced by its much lower mean density, 3.3 times that of water as compared to Earth's 5.5 times that of water. Another way of saying the same thing is that the Moon is made of material that looks more like rock from Earth's mantel than like the overall composition of Earth.

The Moon's composition of certain isotopes exactly matches that of Earth, however, it doesn't match those of bodies from elsewhere in the Solar system.

The collision theory explains the Moon's lack of water and lightweight volatile compounds: The impact heated the debris to high temperatures, and all volatiles turned to gas and escaped into space.

One older theory, that the Earth and Moon grew side by side, doesn't explain why one contains iron and the other doesn't.

A second old theory, that the Moon formed far away and was captured by Earth, violates the isotope evidence that they formed in the same location. Also, the Moon would have either hit the Earth directly or received a gravity kick that set it flying off into deep space. Besides a body as big as the Moon that formed from the same material as other planets would have an iron core like Venus, Earth and Mars.

A third theory states the Moon spun off the outer layers of Earth, violates energy and angular momentum considerations. This model can't explain the total spin rate of the Earth-Moon system. Both the Earth and Moon would have to be spinning four times faster than they actually are. The impact seems to be needed to blow the debris into orbit.

2. For the next 200 million years or so, the Moon was in a molten state.
History of the Moon

4.4 Billion to 4 Billion Years Ago
1. The Moon eventually solidifies into the three main sections of: core, mantle, and crust.

4 Billion to 3.8 Billion Years Ago
1. Around four billion years ago, the bombardment of asteroids produced the giant (Mare) craters we see today.

3.8 Billion to 3 Billion Years Ago
1. Iron-rich lava pours through the cracked basin (crater) floors flowing like motor oil, over the bottoms of these deep basins (craters) Thus, the rock (lava) at the bottom of these basins is much younger than the basins they fill. This formed the maria (dark areas) we observe today.

2. On Earth, single-celled life had just emerged. However, for all intents and purposes the Earth was still uninhabitable, its air unbreathable. The geological processes on Earth were just beginning. On the Moon, the geological story was nearly over; both internal and external activity were coming to a close.

3. Other Mare magmas rapidly erupted in sprays and fire fountains originating several hundred kilometers below the surface. Shooting into the lunar sky, they formed droplets that usually solidified as glass spheres, piling up near their vents and blanketing the ground around them. Apollo 17 Astronauts Jack Schmitt and Gene Cernan, found tiny orange glass spheres during their exploration of the lunar surface.

4. Around three billion years ago significant volcanic action came to an end. The Moon looks today as it did three billions years ago.

3 Billion to 2 Billion Years Ago.
1. Lunar evolution comes to an end. The Moon has cooled to the point where the upper crust is completely solidified and lava could no longer break through and erupt.

Lunar Structure

Sections of the Moon
1. Core
   a. Most scientists believe that the Moon’s core has a radius of about 700 km (434 mi.). Seismic data reinforces the view that the Moon’s core is unlike the Earth’s metallic core. Probably the lunar core consists of partly molten silicates, with a small metallic center.

2. Mantle
   a. A rough estimate would place it somewhere between 800-1,000 km (496-620 mi.) below the lunar crust. It may be composed mostly of pyroxene and olivine, minerals containing silicon, oxygen, calcium, magnesium, and iron.
3. Crust
   a. The Moon's crust on the side that faces us is approximately 60 km (37 mi.) and the
      thickness on the far side is about 130 km (81 mi.). This is well over twice the
      thickness of the Earth's crust. Heat flow from the deep interior through the lunar
      crust is no more than about a third of that for the Earth. Therefore, thermally driven
      processes cannot be nearly as important as for the Earth.

INFORMATION

Lunar Rocks

A. Highland rocks are light gray, with well defined crystals, representing the original Lunar
   surface. They are nearly identical to anorthosite a rock found here on Earth. The well defined
   crystals indicates a slow cooling process.
B. Mare rocks are dark in color with no crystals. The lack of crystals indicates a fast cooling rate.
   Basalt rocks, which are volcanic in origin make up the floor of the mare.

INTERPRETATION

Given Diagrams A and B below which one represents a slow cooling rock; and, which one is a
fast cooling rock. Likewise which one could be a highland lunar rock and which one could be a
Mare basalt rock. Explain why

DIAGRAM A

ANS: Basalt, Mare, No crystals
     Fast cooling

DIAGRAM B

ANS: Highland, crystals,
     slow cooling
LESSON 9: Lunar Weather

INFORMATION

Atmosphere

A. There are several factors which contribute to the formation of an atmosphere. One of these factors relates to volcanic activity, which produces out gassing. Volcanic activity results from the radioactive decay of elements deep in the interior of the celestial body. When a radioactive element such as Thorium decays it gives off energy in the form of heat.

B. Regarding the inner solar system: If you're smaller than the Earth you are geologically dead because by now you've run out of radioactive elements. Thus, with no heat source volcanic activity ceases and so does out gassing. Without out gassing there can be no atmosphere. A celestial body smaller than the Earth has less gravity; therefore, any atmosphere that was once present can't be sustained if geologic activity stops.

Twinkle, Twinkle, Little Star...
1. Stars are round because of gravity. Why do we draw them with points? The reason: Our constantly moving atmosphere which contains air, dust, and water vapor, bends the feeble starlight giving the stars the appearance of points. Therefore, stars when viewed from the surface of the Earth appear to twinkle. On the Moon stars do not have points and they don't twinkle because there is no atmosphere surrounding the Moon.

INTERPRETATION

1. Using the Earth atmosphere diagram below will stars twinkle more at “A” or “B.” Explain B. Because the atmosphere is thicker along the horizon and thinner when one looks straight up.

```
“A” (Zenith or straight up)

Atmosphere

Earth

“B”. (Horizon)
```

2. Do stars twinkle more during the summer or winter? Explain Summer because of increased humidity.

3. Stars do not twinkle when viewed from the surface of the Moon. Why No atmosphere.
INFORMATION

Sedimentary Rocks

A. An atmosphere must be present in order to have weathering and erosion like: wind, rain, and freezing and thawing. One rock type, Sedimentary...is the result of Igneous Rocks broken down into its individual minerals. The minerals are then transported to an ocean by wind, rivers, and glaciers and deposited by their weight. Over time the minerals are naturally glued together by calcium carbonate—(nature's glue). As the minerals pile up their weight along with the "glue" forms a rock type called sedimentary. Sedimentary rocks are usually found in horizontal layers because of varying rates of flow from rivers, glaciers, etc. and periodic changes in the atmosphere.

INTERPRETATION

1. Can sedimentary rocks exist on the Moon? Why or why not? No, because water has never existed on the Moon; therefore no oceans. Secondly, the Moon has no atmosphere; therefore, there can be no weathering or erosion. Without these two ingredients, sedimentary rocks cannot exist on the Moon.

2. Could layered rocks exist on the surface of the Moon? Yes, even though layered rocks could exist on the Moon they are not related to the layered rocks found in sedimentary rocks. Layered rocks on the Moon are the result of one lava flow on top of another. This is typically found on the floors of the Mare.

3. Will footprints left on the lunar surface left by the Apollo astronauts stay there forever? Yes, in theory. Since the Moon has no weathering or erosion there appears to be nothing that would destroy a footprint. However, if an asteroid landed in the area of a lunar exploration site then the footprints might be wiped out. Otherwise, they'll stay there forever.
LESSON 10: Moon Illusion

INFORMATION

Moon Illusion

A. When the full Moon (Sun) is rising or setting, it appears larger than it does when viewed much higher in the sky. By sighting through a narrow cardboard tube or something similar you can measure the angular size of the Moon near the horizon. A few hours later you should measure it again. Under both circumstances you will find that the results are identical.

B. Some people think the atmosphere (heavier near the horizon) produces differential refraction. If this were the case, the Moon would appear to be flatter and shorter, not larger. However, the thick atmosphere near the horizon does produce apparent color changes of the Moon and Sun. Others have said that foreground objects near to the observer affect in some strange way the perception of the observer. This is false because pilots flying at high altitudes have also observed the "Moon Illusion."

C. INTERPRETATION

The Ponzo Illustration - presented by Mario Ponzo in 1913

1. In DIAGRAM A, Which of the two blocks is larger? Two blocks of exactly the same size were inserted between the tracks. The farther of the two blocks appears significantly larger than its nearer companion. IN DIAGRAM B, which man is the tallest? Measure the man on the far left and then measure the one on the far right.

DIAGRAM A

2. According to Carl J. Wenning, Physics Dept., Illinois State University

"...the distance to the sky appears to be a function of where we direct our attention toward it. The sky nearer the horizon appears much more distant, say, than the point directly overhead. Why we perceive the sky in this way. It is against this changing background that we see the Moon. If backgrounds can influence our perception of the size and nature of foreground objects, why can't the sight of the Moon be influenced in a similar manner?"

"...When we see the Moon against a more distant horizon it appears larger than when we see it against a much closer one. The Moon illusion, appears to be nothing more than the Ponzo Illustration inverted!"
Our Nearest Neighbor
"The Ultimate Space Station"

I. INTRODUCTION

The Moon, goddess of the night. Nothing has so captured the eye and mind of mankind. She has shown down since the continents and oceans formed, as well as the beginning and end to a countless number of life forms.

Sometimes she can haunt the daytime sky and at other times she can dominate our dark dreams during the night. Her changing face marks our weeks and months. She beckons and all things respond. What makes the grunions run or brings the starfish out to feed. What alone orders the tides of Earth’s oceans or eclipses the Sun. The Moon, which is so enchanting, so mysterious and so far away that only in its dreams could man touch her desolate beauty. Then, on July 20, 1969, the dream was realized; man had set foot upon her surface.

II. GENERAL FACTS ABOUT THE MOON

 v All Figures are Approximate

A. Diameter
   1. \(3,476 \text{ km (2,155 mi)}\), which is about one-fourth the diameter of the Earth.
      Also, \(1/400\) the diameter of the Sun
      \[\begin{align*}
      \text{Diameter of Sun:} & \quad 1,400,000 \text{ km (864,000 mi)} \\
      \text{Diameter of Earth:} & \quad 12,900 \text{ km (8,000 mi)} \\
      \text{Diameter of Moon:} & \quad 3,475 \text{ km (2,000 mi)}
      \end{align*}\]

B. Average Distance From the Earth
   1. \(384,000 \text{ km (238,328 mi)}\), which is about one-fourth of a million miles.
      \[\text{Distance to the Sun:} \quad 150,000,000 \text{ km (93,000,000 mi.)}\]

C. Age
   1. \(4.6 \text{ billion years old}\).

D. Climate
   1. It is a dry, airless barren place.

E. Gravity
   1. One-sixth of the Earth’s gravity. Therefore, if you weigh 180 lbs. on the Earth you will weigh 30 lbs on the Moon.
   2. Escape Velocity: \(2.4 \text{ km/sec}\)

F. Temperature
   1. Night side: \(-118^\circ\text{C (-180^\circ F)}\)
   2. Day side: \(+115^\circ\text{C (+240^\circ F)}\)
G. Inclination
1. Moon's orbital plane to the ecliptic is 5°
2. Moon's axis is nearly perpendicular to the plane of its orbit.
3. Inclination of axis is 6.5°

H. The Sun and the Full Moon Appear to Have the Same Diameter
1. The Sun is approximately 400 times the diameter of the Moon and it is also about 400 times as far away from the Earth as is the Moon. Also, both the Sun and the Moon are just about 108 times their own diameters away from Earth. Thus, we can conclude that any round object like a dime or a beach ball, when held about 108 times it's own diameter away from the eye, will have the same apparent diameter as the Sun or the full Moon.

I. Earthshine
1. Earthshine is light, which has traveled from the Sun to the Earth, reflected towards the Moon and then reflected back towards the Earth. The ideal time to observe Earthshine is when the Moon is in its waxing crescent phase just after sunset. However, it can also be observed during the phases of: first quarter, third quarter and waning crescent. The latter two being observed a few hours before sunrise when the sky is still dark.

2. It is very faint because only a small part of the sunlight reflected from the Earth hits the Moon. The Moon reflects only seven per-cent of this into space. A tiny fraction of this finally comes back to Earth. When you look for Earthshine, note that the waxing crescent Moon, because it is brighter seems larger.

This part of the Moon (Earthshine) is barely visible on the Earth

2. Waxing crescent earthshine is also known as: "The old Moon in the new Moon's arm."

J. Best Time to Observe Surface Structure (Relief) or How to See the Moon's Craters and Mountain Ranges in 3-D
1. Using a telescope or binoculars, look along the TERMINATOR (The line separating daylight and darkness) during the waxing crescent, first quarter, third quarter or waning crescent phase of the Moon. At this location, shadows will be at their longest on the lunar surface; therefore, mountain ranges, as an example, will stand out in bold RELIEF. Relief is a 3-D (three dimensional) effect showing the distance between high and low elevations. It give one the feeling of flying over the craters and mountain ranges.

2. The full Moon is the worst time to observe relief because there are no shadows on the lunar surface. However, the full Moon provides us with an opportunity to observe all of the surface features like: mare, highlands, craters, valleys, rills, rays and the: "Man in the Moon," "Frog in the Moon," "Rabbit in the Moon," and "Jack and Jill."
K. Moonrise and Moonset
1. The Moon will rise or set an average of 50 minutes later each night for people living in the middle latitudes. This will vary from month to month as well as from latitude to latitude.

2. During the winter in the northern hemisphere, the full Moon will rise from the northeast and it will set in the northwest. By comparison, the Sun will rise from the southeast and it will set in the southwest. The full Moon will be very high in the sky and it will travel a very long path; whereas, the Sun will be very low and travel a very short path in our sky. During the summer the opposite will occur. Thus, the position of the full Moon this month represents the approximate position and path of the Sun six months from now.

L. Harvest Moon - Hunter's Moon
1. A Harvest Moon is a full Moon on or near the autumnal equinox (September 23). At this time the angle between the ecliptic and the horizon is at a minimum; therefore, the Harvest Moon will rise about 20 minutes later each night. Thus, the full Moon rises earlier and stays longer for several nights in a row. The next full Moon following the Harvest Moon is known as the Hunters Moon. A similar effect is observed in corresponding southern hemisphere latitudes around March 21, the vernal equinox.

2. The angle of the full Moon's path relative to the eastern horizon is largest during the spring equinox. This causes the Moon to be farther below the horizon from one night to the next, which means that the time delay between moonrise times is longer in spring than in autumn.

3. The full Moon for each month has a name/s and they are:

<table>
<thead>
<tr>
<th>January</th>
<th>Wolf, Old, After Yule Moon</th>
<th>July</th>
<th>Thunder, Hay or Buck Moon</th>
</tr>
</thead>
<tbody>
<tr>
<td>February</td>
<td>Snow, Hunger Moon</td>
<td>August</td>
<td>Green Corn, Sturgeon, Grain Moon</td>
</tr>
<tr>
<td>March</td>
<td>Sap, Crow, Worm, Lenten Moon</td>
<td>September</td>
<td>Harvest, Fruit Moon</td>
</tr>
<tr>
<td>April</td>
<td>Grass, Pine, Frog, Egg Moon</td>
<td>October</td>
<td>Hunter's Moon</td>
</tr>
<tr>
<td>May</td>
<td>Planting, Flower, Milk Moon</td>
<td>November</td>
<td>Beaver, Frost Moon</td>
</tr>
<tr>
<td>June</td>
<td>Rose, Strawberry Moon</td>
<td>December</td>
<td>Before Yule, Cold</td>
</tr>
</tbody>
</table>

Long Night Moon

M. "Once in a Blue Moon"
Few experts agree on why a blue moon - a second full moon in one month - is called a "blue moon." It has nothing to do with its color. They have become a part of our culture, largely remembered from the popular Rodgers and Hart standard: "Blue Moon, you saw me standing alone, without a dream in my heart, without a love of my own."
Blue moons occur once every 2.7 years and come about because the modern calendar's 12 months do not coincide with the moon's 29 day cycle. Thus, the phrase "once in a blue moon," simply means an event that doesn't occur very often. Another unusual occurrence is a real blue moon that really is tinted blue. This takes place when something in the atmosphere blocks the red component of sunlight. A blue-tinted moon was seen over much of the world after the 1991 eruption of Mount Pinatubo in the Philippines. In the 1940's the smoke from a major forest fire in Canada caused the full moon to look blue.

The origin of the term itself is obscure; however, there are some theories. One explanation links "blue moon" to the Old English word "belewe" which means "to betray." According to that theory, the second moon in one month betrays the count of one full moon in one month.

Some say it may have come from the French word for double. Others argue it came from ancient cultures in Egypt or Crete and was a symbol of good fortune. Or the phrase may have sprung from agricultural traditions of colonial America along with derivations such as harvest moon and hunter's moon. Whatever, it is lost in the mists of history.

Blue Moons have occurred in June of 1996. The one previous to that occurred in September of 1993. Blue Moon's occurred on January 31, 1999 and on March 31 1999 making double Blue Moons for that year. The last time we had double Blue Moon's occurred in January and March of 1961; and, before that 1915. The only month that can't have a blue Moon is February—not enough days.

Another version: James Hugh Pruett wrote a 1946 piece for Sky and Telescope regarding a Blue Moon after apparently misinterpreting a complex 1937 article in the Maine Farmer's Almanac that essentially, but not clearly, said: A Blue Moon Occurs when a season (three months) has four full moons, the third, rather than the fourth, is called the Blue Moon due to the seasonal names given to each moon. By this definition Blue Moons are only found in the months of February, May, August, and November since these months are at the end of each season. Sound confusing?

Pruett's mistake went unnoticed for decades. A 1980 National Public Radio story about Blue Moons used the wrong definition. In 1986, the board game Trivial Pursuit repeated the error. Sky and Telescope's editors think Pruett's mistake probably led to the popular modern mis-definition of "Blue Moon," it's unclear where the Maine Farmer's Almanac came up with the rule. The almanac is defunct. Although the term "Blue Moon" has existed for centuries, it had no precise definition until 1937.

By either definition Blue Moons occur about every 2.7 years. The last Blue Moon as defined by the Almanac was in May 1997. The next will be in February 2000. Although purists may subscribe to the almanac's point of view most people believe Pruett's error will prevail.
N. Lunatic

Lunatic refers to someone who is out of one's mind. It comes from the Latin word Luna which means Moon.

During the 1700's, England enacted laws to protect people whose madness coincided with the full Moon. These lunatics, as they were referred to, were distinguished from the chronically insane by law.

In 1842, the British Parliament passed the Lunacy Act. This law spelled out the relationship between the lunar phases with the various mental states. Extreme madness coincided with the new and full Moon. The most lucid periods occur during 1st and 3rd phases. Statistics have proven that there is no correlation between phases of the Moon and behavior.

In 1980, a hospital in New York declared that they had more births during a full Moon than any other time of the Month. Five years later the same hospital declared they had more births during a new Moon. In 1990, this hospital declared there was no correlation between the phases of the Moon and births.

O. Does the U.S.A. Own the Moon by Virtue of our 1969 Landings?

No! The United Nations, in 1967, developed the international space law titled: Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies. It embodies the principle that territory in outer space is not subject to national acquisition. But it wasn't until the 1979 Agreement Governing the Activities of States on the Moon and Other Celestial Bodies that the Moon (and other bodies within our Solar System, except for the Earth) was officially proclaimed to be the common heritage of mankind.
The Race to the Moon

The Space Race

IN a sense the race to the Moon began on October 4, 1957, when the former Soviet Union successfully launched a satellite called Sputnik into Earth orbit. The implication of this event was clear to the world, especially in America. In the late 1940's the Soviet Union successfully exploded an atomic bomb. Now the thinking was, they had an atomic bomb and the means to deliver it via their rocket technology. America did not have a comparable rocket program; and thus, if the Soviets launched a nuclear weapon towards the United States, the United States would not be able to adequately respond in kind.

On April 12, 1961, the Soviet Union demonstrated they had heavy lift rockets by successfully launching and orbiting the first human in space, Cosmonaut Yuri Gagarin. On May 5, 1961, America answered by placing Alan Shepard in sub-orbital flight via a rocket. However, America did not have the rocket power or technology to place a human into Earth orbit.

On May 25, 1961, before a joint session of Congress President, John F. Kennedy, announced to the world that America would land a man on the Moon and return him safely to the Earth before the end of the decade. With just 16 minutes of sub-orbital space flight Kennedy had challenged the Soviet Union to a race to the Moon.

Through the 1960's America's Space Program went through three phases: Project Mercury, a one manned spacecraft; Project Gemini, a two manned spacecraft; and Project Apollo, a three manned spacecraft which ultimately took American's to the Moon by the end of the decade. The Soviet Union went through similar stages; however, in the end their going-to-the-Moon rockets failed to work. Think of the irony, our rockets didn't work properly at the start of the space race and theirs failed to work at the end of it. We sent nine Apollo manned missions to the moon, six of which landed.

The benefits to humankind of sending men to the Moon are in the thousands. Here are a few:

Benefits of Manned Space Exploration

Since 1964 almost 50,000 new technologies have been reported from NASA and contractor laboratories. From among these, the space agency has been able to document 550 commercial uses. Commercial applications of these breakthroughs probably number more than 20,000. said Henry Clarks, director of technology utilization at NASA. U.S. companies have reaped billions of dollars by applying space research to commercial products and processes, he said.

"Down the line, 20 to a hundred years from now, they will equate the space program, in terms of human benefit, with the Industrial Revolution," says Douglas Morrow a NASA advisory council member.

Project Apollo was the epicenter for a phenomenal movement of aerospace technology that still benefits humankind today.
Call them spinoffs, offshoots, technology twice used, whatever.....going to the Moon created thousands of jobs, beneficial products and processes. It involved industry, small businesses and entrepreneurs. They continue to serve as the backbone of America's productivity and competitive spirit in the marketplace.

From health, medicine, environment, consumer and recreational products, to public safety transportation and manufacturing technology, the Apollo program proved a wellspring for innovation and transferable technology.

RUNNERS SHOES
On July 20, 1969, Neil Armstrong donned a lunar boot and took his first step on the lunar surface. Today thousands of runners and joggers around the world are cushioning the pavement's blow with the same shock-absorbent soles.

DIGITAL IMAGING PROCESSING
In order to lay the groundwork for Apollo astronauts to set foot on the Moon, better detail of the Moon's surface was needed. In the mid 1960's the Ranger series of Moon probes yielded, by way of an analog signal, upwards of 17,000 high-resolution lunar images. Jet Propulsion Laboratory (JPL) engineers developed the technology known as digital image processing, a method that brought out greater detail in the Ranger photos of the lunar landscape.

Landsat
This technology was later used in NASA's Landsat series of remote sensing satellites to discern to a greater degree the surface features on Earth. Crop forecasting, rangeland and forest management, as well as mineral exploration and water quality evaluation using space born sensors have benefited from earlier, Apollo-related digital image processing work. Many digital image processing packages now being used with personal computers are direct offsprings of NASA's earlier need to enhance lunar data. Digital image processing has been broadly applied to a number of fields.

CAT & MRI
Computer Aided Tomography (CT or CAT) and Magnetic Resonance Imaging (MRI) are methods developed from digital image processing to enhance images of organs within the human body for diagnostic purposes.

HICAP
NASA's Computer Software Management and Information Center (COSMIC) located at the University of Georgia developed the HICAP computer program for use by medical radiologists to distinguish between healthy and diseased tissue in body images.

Dermatology
JPL-developed software led to a technique called "photocrinometry" - a way to deduce lunar surface elevations for topographic maps. Similarly, this digital image processing software has proven useful to research, evaluate and demonstrate skin care products. It turns out the topography of human skin, with its own hills, folds and furrows, and the Moon's "face" have much in common.
COOL SUIT  (Liquid Cooling Garment)

Victims of a rare skin disease called hypohydrotic ectodermal dysplasia (HED) suffer from the absence of sweat glands needed to allow body heat to escape. Space technology came to the rescue in the form of the Liquid Cooling Garment used by the Apollo astronauts. This garment, which looks like long underwear with tubes running through it, is cooled by a heat exchanger powered by a mini-pump through a network of fluid-filled tubes. It is capable of eliminating 40-60% of stored body heat.

A line of "cool suit" designs, from full-body coverings to headcaps and torso vests, are now being used, stimulated by work on space suits. The Multiple Sclerosis Association of America has provided the cool suits to a number of research centers that assist victims of multiple sclerosis.

HEART MONITORING

If Apollo's goal were only to land a robot on the Moon's surface, a host of medical technologies would not have been advanced as rapidly.

An assortment of micro devices was needed to maintain a long distance medical eye on Apollo astronauts. Microminiaturized circuitry, sensor and battery technologies led to several mechanisms that served medical functions.

Paramedic Rescue Teams use this technology to assist those who are being transferred to a medical center. Telemetry of one's vital signs can be transmitted to an emergency room. By the time the victim arrives at the emergency room physicians are ready to accept the patient.

Pacemakers
One product stemming from the Apollo endeavor was an implantable pacemaker, along with a physician's console containing the programmer and data printer. The physician can communicate with a patient's pacemaker by means of wireless telemetry signals transmitted from a unit held over the person's chest.

SPACE FUEL

Today, liquid hydrogen, which was used to fuel the upper stages of the Saturn V rocket, has applications ranging from food processing to strengthening metal alloys.

FIRE PROTECTION

The fibers used in the Apollo spacesuits are now used in commercial airline seats making them six times more fire-resistant.

As the Apollo Command Module reentered the Earth's atmosphere at 25,000 mph its exterior temperature rose as high as 5,000°F. To dissipate heat and keep the spacecraft's internal temperature comfortable for the astronauts inside, an ablative coating was used. This material, while burning off, dispelled heat energy, but also formed a second protective coating that obstructed heat penetration beyond the outer surface.
From this a spinoff product was created called Charteck Fireproofing. It widely used in crude oil processing and chemical industries and in other industries where risk of fire is great. Using the spray-on epoxy coating means buying time in a fire environment.

After the Apollo I fire that took the lives of three astronauts, NASA intensified its fire safety research. As a result, a chemically treated fabric was developed that would not burn, melt or produce noxious fumes. It was then selected for Apollo garments and later found a wide range of applications including fire-retardant paints, foams and fire blocking coatings. It is used on the interiors of modern day aircraft as well as the garments used by firefighters.

Also inspired by work on Apollo's portable life support systems for moon walking was a lightweight breathing system, including facemask, frame, harness and air bottle. Aluminum composite material was used, making the frame and harness less cumbersome to put on and take off. Firefighting equipment now incorporates materials and technology promoted by the Apollo program.

WATER FILTRATION AND PURIFICATION
Water filtration and purification used on board the Apollo spacecraft provided clear, good tasting and odor-free water by removing toxic contaminants and water processing agents such as chlorine. Apollo purification hardware used silver ions to kill bacteria, plus copper ions to nullify algae build-up. This space technology is now widely used in commercial products for pool and spa upkeep, for whole-house units and in developing nations that have contaminated water.

PHYSICALLY CHALLENGED
Apollo's Lunar Rover Vehicle was used on three missions: Apollo's 15,16 & 17. This vehicle greatly enhanced the exploration range of the astronauts. The rover used a single, airplane-like joystick to maneuver the vehicle across the moonscape at speeds up to 10 mph. The joystick was necessary since bulky pressurized space suits prevented the astronaut driver from rotating a conventional steering wheel.

The space-developed technology to control a vehicle with one hand is now being utilized for physically challenged individuals. The Apollo technology allows the disabled to operate an automobile or van easily, greatly enhancing their independence. Commercial development of this Apollo spin-off has been spurred by joint funding from NASA and the Veterans Administration.

VIRTUAL REALITY
Visual simulators built to project images of Earth orbit, docking and lunar landing scenes for training astronauts stimulated a product line of telescopes, wide-angle eyepieces, virtual reality imaging systems. Collectively the optical systems developed for Apollo proved useful for military services, aerospace companies and a wide range of commercial businesses.
THE TRUTH BEHIND TANG, TEFLON and VELCRO

Tang
Tang had been invented prior to the first liftoff of a U.S. astronaut. The powdered beverage was far from being a rage. However, when NASA picked the drink to be on board American spacecraft, due to its nutritious content and small size, sales of Tang skyrocketed.

Teflon
Teflon had its origins as far back as the late 1930's. Teflon saw its first practical application as a covering material for antennas mounted on the tip of rocket warheads.

Velcro
Velcro was "unearthed" in the 1930's by a scientist hiking in the Swiss Alps who had a close encounter with cockleburs. He noticed that the cockleburs would stick to his socks. Returning to his laboratory, the scientist studied the cockleburs under a microscope, noting their small hook-like ends. A manufacturing process later made matching strips with tiny hooks and adhesive pile.

EYECARE and PROTECTION

Sunglasses
The coating on the Apollo spacesuit helmet visor spawned a scratch-proof sunglass to withstand the most rigorous family vacation.

At Foster Grant Corp. in Leominster, Mass., Bill Marcotte, director of sunglass marketing, says NASA technology helped his company compete against a flood of Asian-made imports. Foster Grant's Space Tech sunglasses, are 10 to 100 times more scratch resistant than those of the company's rivals, he says. The company, which has exclusive rights to the NASA technology, sells more than 3.5 million of the Space Tech sunglasses each year.

Eyecare
NASA backs many more long term research projects posing rich rewards for society. NASA and the Johns Hopkins Wilmer Eye Institute in Baltimore, for example, are adapting image processing technology-originally used in satellites and now being enhanced for the space station-for special eyeglasses for people with severely impaired eyesight. The glasses will perform as a television camera on the outside world, altering and enhancing visual images as needed for the patient.

COMPUTER TECHNOLOGY

In order to go to the Moon astronauts had to rely on computers. The computers of the 1960's had to be scaled down in size and upgraded in their ability to do work. Therefore, today's computer technology is the direct result of the testing and utilization of computers in the space program.
Many companies annually tap into the NASA Computer Software Management and Information Center at the University of Georgia, which provides training and assistance in 1,200 software packages created for the space program. NASTRAN, a structural analysis program developed to help aerospace engineers test airplanes and spacecraft by computer simulation, has been the most widely accepted commercially. The program has been used to design everything from roller coasters like Space Mountain at Walt Disney World to automobiles—most recently the Honda Acura Legend.

More Spin Offs...

Much of the research is basic science, which usually takes a long time to affect our daily lives. Commercial research is just getting started, but it represents an enormous opportunity. “It is the growth of business into space that would bring the benefits of space down to Earth and enrich the everyday lives of all Americans,” says C. Blake Powers at the Marshall Space Flight Center in Huntsville, Alabama. Toward that end, NASA is sponsoring Commercial Space Centers to encourage the commercialization of space by providing businesses with the opportunity to improve existing products and processes, as well as to develop new products.

One example is an extremely lightweight insulating material called Aerogel, which is 90% to 99% air. More than 800 product applications already have been identified for it. “A block of Aerogel the size of an average human weighs only a pound yet can support the weight of a small car,” says Powers. An inch-thick slab can shield even a delicate flower from the heat of a blowtorch. And this is only the beginning.

Every time you put on your running shoes, quartz watch, scratch-resistant sunglasses, and insulated jacket; or, stick your laptop computer under your arm and go somewhere, did you remember to thank NASA?

Thanks to the Apollo project of landing a man on the Moon we are currently benefiting from about 1,300 innovations that have entered U.S. industries. Firefighters’ suits, cardiovascular tools used in open heart surgery, bi-medical sensor patches used in transmitting current vital signs of accident victims to hospital emergency rooms; cordless drills and telephones, coatings used on pizza makers and general cookware, and so on—NASA made them all possible.

The drama of Neil Armstrong’s first step on the Moon may seem like ancient history to students. But the next time a student asks, “What good is the space program?” You can reply, “What good are your Nikes?” Here is a web site: http://nctn.hq.nasa.gov/succe

Use of Robots
It has been suggested by many that robots should be used to replace humans in the exploration of space. The reasons are: Robots can do more than humans (not true), they are far less expensive; there are no health risks to robots; and, robots don’t require food water and air to breathe. Robots can be used for travel to the outer solar system and beyond; and, if there is a catastrophic accident we’d have no one to mourn.
Now let's compare and contrast the pros and cons of human space exploration. First, robots can't necessarily do more than humans. In many instances humans can solve problems easier than robots simply because it takes time to transmit signals from Earth to command a robot at some distant location. Robots do not have peripheral vision, nor can they "experience" the moment and explain what it was like later.

Second, robots maybe less expensive but their return value is also minimal. For instance, if there had been Apollo robots in place of humans the development of bio-sensors may have been greatly reduced since robots do not require them. Thus, the benefit to humans here on Earth would've been lost. Human exploration initially is more expensive but in the long run the payback far out ways the costs.

Third, there are no health risks to robots and there are definitely health risks to humans especially on a long trip to Mars. Exploration of the outer Solar System and beyond, at this point in time is remote because of a lack of technology and will. However, future generations will recognize the significance of going there and will overcome the technology problems. Until that time robots are the answer for exploration requiring long journeys.