EVERYTHING MOON

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A Teacher Guide and Activities for Teaching and Learning about the Moon

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Everything Moon: A Teacher Guide and Activities for Teaching and Learning about the Moon

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This book is dedicated to my husband Bob and our two wonderful children, Matthew and Jennifer. By the light of the silvery Moon, true love shines through.

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How to Navigate the Book

The science discussed in this text has been gathered primarily through data collected during orbital lunar missions, classic observations of the Moon from Earth, lunar rock samples collected by the astronauts during the Apollo program, and data from instruments they left on the lunar surface. Most of the content has been transcribed from various individuals who either conduct lunar research or write curriculum to support science in the K-12 setting. The text is primarily for teachers as a content work, and includes engaging investigations for reinforcing concepts in several chapters.

Science misconceptions related to the Moon are included in bold print in the first paragraph of relevant chapters. Many of the investigations are designed to mitigate misconceptions if conducted properly. If you have any questions, please feel free to contact the author.

Please make use of:

- The comprehensive glossary for common words in the book, located at the end of Chapter 8.
- The References and Additional Resources section contains suggestions for further reading, as well as current information and research related to the science of the Moon.
- The Appendix, which includes all additional documents necessary to conduct investigations – specifically for observing the moon, the Galileo sunspots, and the Bowen's Reaction Series schematic to help students develop the concept of differentiation of minerals out of magma.

PROLOGUE

Selene was the Greek goddess of the Moon—associated with the Roman goddess Diana and the Greek goddess Artemis—who traveled in the sky with a God of the Sun, Apollo. He traveled throughout the day and Selene took over the journey at night. Considered a passionate goddess, Selene represents human desire associated with the Moon.

—Kerenyi, *The Gods of the Greeks*

Growing up in New England with little or no light pollution from nearby towns, the view of the night sky was clearly awesome. Stars and planets, comets and meteors, everything one could imagine out there beyond our little part of the vast universe was there to see. Walking along the shore of Lake Willoughby in Vermont on a summer evening, looking at the reflected face of the Moon on the water, I never once thought about where the Moon came from or that only one side of the Moon faced Earth.

It was not until I was nearly an adult that the science of the sky took hold and became one of my passions. I started questioning the "what and why" about stars, planets, comets, meteors, and our Moon. Now they had a different meaning and purpose to my mind. I had questions and needed to find answers. I began to question everything around me in much the same way I wanted everyone to question the world around them. Science, it seems, is a continuing process of asking questions, seeking answers, solving problems, and then finding new questions to answer. It is a cycle of thoughts, questions, answers, and evidence—over and over again—until conclusions can be drawn, (or maybe not).

By the time I realized I was hooked on the Moon, I was almost an adult. In driver's education class during my seventeenth summer, our teacher dragged us inside to watch a live news show – at the Moon! That was when I understood why the Moon held my attention. When Neil Armstrong first stepped on the Moon in July of 1969, I couldn't help but wonder what it must be like to look back at the Earth from the surface of the Moon, to walk on the lunar surface and kick up dust and bounce along the surface, to be somewhere in the solar system where no person had ever set foot before. It was at this point that my interest in the Moon progressed from simple witnessing of the full Moon on a clear night, or checking the tide chart for a coastal swim. The Moon had become more.

Lunar science is not always an easy science. Every day, lunar scientists make new discoveries about the Moon. Some new discoveries are as simple as the distance between the Earth and Moon on a given day; others are incredibly complex theories about the origin of the Moon and its geologic history. Whatever the science, the more we know about our nearest neighbor, the more we know about our planet—and the more we will know about our solar system and the universe.

Astronomy is not a typical experimental science. Although laboratory experiments (spectral analyses, for example) can provide information to the science of astronomy, it is through systematic observations of celestial objects (i.e. their motions and effects in space relative to each other) as well as the modeling of these observations that provide explanations for what is observed. Models created to explain observations include computer models and/or physical models. However models are often difficult to understand or can result in confusion if systematic observations are not integrated within them. This makes observation an integral part of the modeling process, which becomes evident when conducting certain activities in this text. Observations of the Moon therefore are no exception.

The Moon, as a celestial body, is observed regularly from Earth. Data is collected using instruments aboard orbiting spacecraft or rovers on the surface of the Moon. As with observations of the planets, stars, galaxies, and other members of the universe, much observation is conducted using ground-based and space-based telescopes that are equipped with onboard instruments such as **photometers** and **spectrometers** to collect data for analyses. With the Apollo Program, the United States sent humans to the lunar surface to collect data, **regolith**, and rocks. Even today, the U.S. and other countries continue to send probes and orbiters to the Moon to better understand its composition, properties, and origins. These missions have provided new scientific studies, including recent findings (2011) from Apollo samples, and significant revisions to hypotheses and theories about the Moon over the last five decades. These factors combine to bring about ongoing discussion concerning hypotheses and theories. This text will follow the guidelines laid out by Michaels et al. in their book *Ready, Set, Science* (2008), which states:

> A scientific theory—particularly one that is referred to as 'the theory of…, as in the theory of electromagnetism or the theory of thermodynamics or the theory of Newtonian mechanics—is an explanation that has undergone significant testing. Through those tests and resulting refinement, it takes a form that is a well-established description of and prediction for phenomena in a particular domain. A theory is so well established that it is unlikely that new data within that domain will totally discredit it; instead the theory may be modified and revised to take the new evidence into account. . . . Indeed, the term 'hypothesis' is used by scientists for an idea that may contribute important explanations to the development and refinement of models and scenarios that collectively serve as tools in the development of a theory. (pp. 4-5)

Introduction

It is the very error of the Moon,
She comes more near the Earth than she was wont,
And makes men mad

—Shakespeare, *Othello*

Throughout human history, the Moon has fascinated us. Myths, legends, lore, and connections to human behaviors and cycles have long been observed, written about, and illustrated. Early humans painted images of the Moon on the walls of caves as it moved daily through the sky. A bone fragment found in a cave in France dating from about 12,000 years ago appears to record the 29-day lunar cycle (Département de la Drôme, France, 1991) with near perfection. Even Stonehenge, an ancient arrangement of huge stones in the United Kingdom, appears to depict a calendar year; the seasons are marked on stone by the Sun at equinoxes and solstices. Fifty-six deep pits dug along the inside circumference of the Stonehenge embankment appear to represent the various positions of the Moon in the night sky, as viewed through imagined posts set into the pits, with two holes representing one lunar day. Called the Aubrey Holes, speculation about the significance of the holes is in debate even today. Even more intriguing is evidence for as many as 240 burials found in these pits indicating that they may well have been England's first cremation cemetery (Riverside Project, University of Sheffield, Sheffield, UK, 2008).

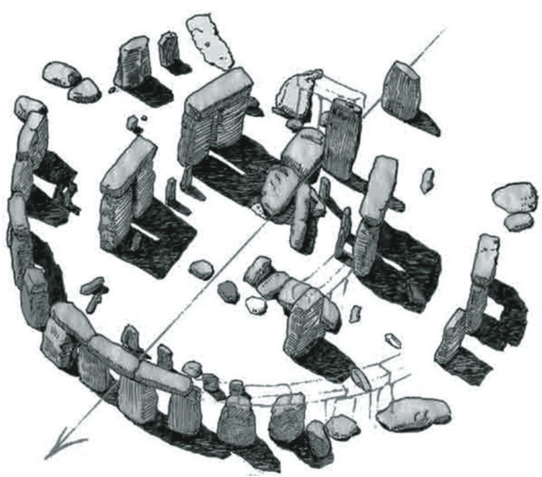


Figure 1: An illustration of the ancient stone formation known as *Stonehenge*. (Author sketch modification from images)

Spiritually, the ancient religions of Egypt, Mesopotamia, Rome, and Greece—a few among many—believed that the Moon possessed mysterious powers. Many cultures' prominent gods and goddesses (the Greeks and Romans, for example) were associated with the Moon, its phases, eclipses, and its motions in space (Buckert and Raffan 1987).

With the development of telescopes in the 1600s, pioneers in astronomy such as Galileo Galilei, Giovanni Basttista, and Thomas Harriot were drawing maps of the Moon. Their maps were rudimentary, based on what they could see from the surface of the Earth. Obviously, with the Moon some 300,000 km away (240,000 miles), they could only associate what they were looking at to what they already knew—what they knew about Earth. For example, Galileo called the dark areas of the Moon *mare* (pronounced MAR-ray), which is Latin for 'sea' because that is what they looked like to him through his telescope. He called the lighter colored areas the lunar 'highlands' because he assumed correctly, that they were mountains.

As modern technology developed and the Space Age was born, our observations of the Moon became better developed. Lunar orbiters and landers and the Apollo Program helped modern scientists gather a wealth of information about its surface features, composition, geomorphology, and about the formation of the Moon. With each mission to the Moon, more lunar mysteries have been uncovered.

This book tells a story about the Moon. Based on common misconceptions in the Sun-Earth-Moon system, much of the book takes you through the geologic history and formation of the Moon, its features, its place in space (phases, tides, and eclipses), through past and current discoveries, and onward to future missions dedicated to unraveling the secrets of our Moon.

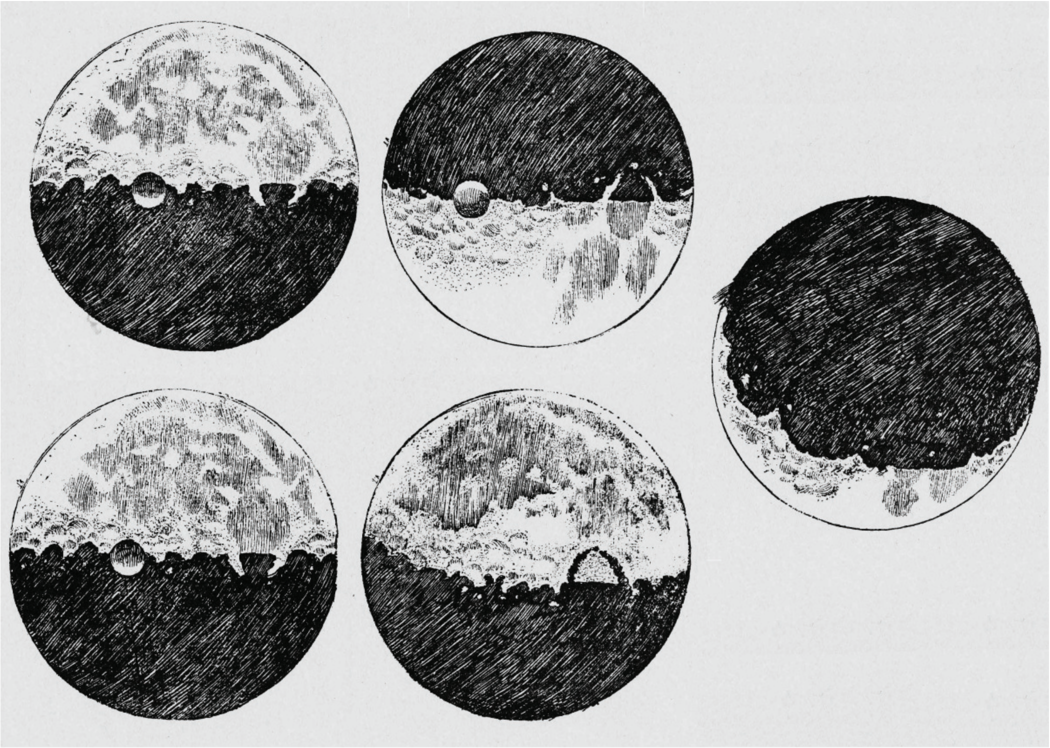


Figure 2: Illustration reproduction of Galileo Galilei's observations of the Moon circa 1600s. (Public Domain)

Misconceptions related to the Moon, Sun and Earth are common. This text addresses many of the misconceptions with content, illustrations, images, and student investigations. It attempts to unravel these misconceptions in order to bring about conceptual change and foster sound scientific knowledge for true understanding.

CHAPTER 1
THE ORIGIN OF THE MOON

The formation of planets is like a gigantic snowball fight. The balls bounce off, break apart, or stick together, but in the end they are rolled up into one enormous ball, a planet-ball that has gathered up all the snowflakes in the surrounding area.

— Claude J. Allègre

I suppose there were moonless nights and dark ones with but a silver shaving and pale stars in the sky, but I remember them all as flooded with the rich indolence of a full Moon.

—Willa Sibert Cather

In the early days, scientists thought that our solar system formed in a quiet and orderly manner – this is not true. In fact, now many scientists think that the formation of our solar system occurred as a series of chaotic, violent, and catastrophic events. From this violent chaos, our solar system formed out of a massive cloud of gas and dust (debris) in a spiral arm of the Milky Way galaxy.

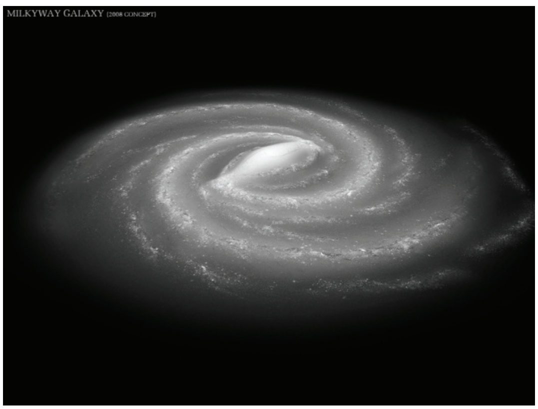


Figure 3: An artistic impression of the Milky Way Galaxy. Notice the spiral arms and the bulging middle. Our solar system is located in a spiral arm some 28,000 light-years from galactic center. (Image Courtesy of NASA)

To envision the trigger for this chaotic event, imagine a massive cloud of dust and gas floating in a spiral arm of the Milky Way. Suddenly, a nearby giant star explodes in a super nova event, or possibly a neighboring galaxy collides with the Milky Way. This caused 'waves' in the fabric of that part of space that squeezed the cloud together and forced it to spin in a single direction. Everything is in chaotic motion. It is within this violent chaos of disrupted gas and dust that our solar system formed.

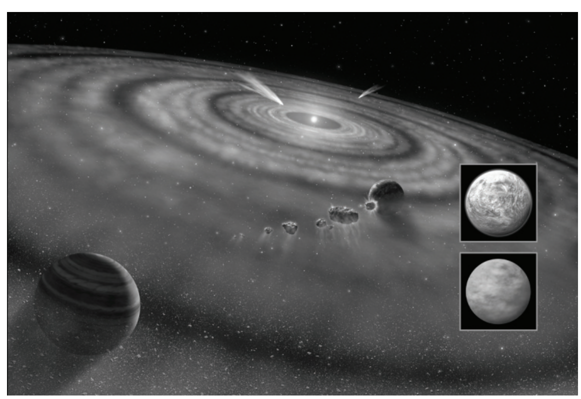


Figure 4: Artistic rendition of the solar system formation. (Image Courtesy of NASA)

During millions of years of chaos, the dust and gas collided and clumped together. It heated up, collided with other hot clumps, and continued to collide and clump. As the clumps grew larger, they gained gravitational force and pulled in even more accumulated material. All the while, most of the cloud mass collapsed inward into the center of the spinning cloud. This collapse formed the solar nebula: a flattened disk (called an accretion disk) of spinning dust and gas.

However, solar system formation had only just begun. The solar nebula grew hotter and denser in the center as more and more material collapsed inward, getting hotter and hotter. The outer edges of the disk, far from the center, remained cool. The Sun formed at that point when enough gas and dust collapsing in the center of the disk was gravitationally strong enough to ignite the fusion process. Hydrogen fused with hydrogen to produce helium and our star began to radiate heat and light. As soon as the Sun was born, it emitted enormous amounts of energy outward and solar winds began to sweep through the remaining cloud of gas and dust. This outward flow of energy from the Sun provided enough pressure outward to keep the star from collapsing under its own weight due to gravity.

Meanwhile, the accretion disk became thinner and thinner—and much cooler—at the outer edges. The clumps of gas and dust remaining in the accretion disc continued to stick together becoming more massive as gravity became stronger, pulling even more material toward the larger clumps. As gravitational forces became stronger, larger clumps became pebbles, then rocks, then boulders, and eventually became large enough to be called planetesimals orbiting the Sun. After hundreds of millions of years, these planetesimals gathered enough debris to form larger objects called proto-planets. Proto-planets collided chaotically with each other, collecting even more debris as much of the remaining dust and gas in the accretion disc was swept up.

Eventually, the gravitationally stronger proto-planets gathered up enough debris to form the planets and moons, and the remaining debris formed the asteroids, meteors, comets, Kuiper belt objects, and the Oort cloud members of our solar system. The cooler icy gases and dust on the edge of the accretion disk (the thin outer edges) formed the outer Jovian planets, the Kuiper Belt objects, and the Oort cloud while the hotter clumps near the center (closer to the Sun) became the inner terrestrial planets.

So, what does this have to do with the origin of the Moon? To be considered an arguable theory of the Moon's origin, the following information must be considered:

- The Moon's low density (3.3 g/cc) establishes that it does not have a substantial iron core similar to Earth's core. (Earth's density is 5.515 g/cm3) (NASA). However, look at the recent science in Chapter 2 about the Moon's core to see what NASA scientists have discovered.
- Moon rocks contain few **volatile** substances (e.g. water), which implies extra baking of the lunar surface relative to that of Earth.
- The relative abundance of oxygen isotopes on Earth and the Moon are identical. Isotopes of oxygen mean that there are oxygen atoms with different numbers of neutrons. One isotope of oxygen has 8 neutrons, another has 9 neutrons, and a third has 10 neutrons. The light oxygen, the one with 8 neutrons, is the most common. This suggests that the Earth and Moon formed at the same distance from the Sun.

So, when we consider possible ways to explain the formation of the Moon, we need to keep these three factors in mind as evidence to support or disprove a theory about its origin. The following is some of what we know and can deduce based on the information we have to date:

Prior to 1984, three major theories related to the origin of the Moon were strongly debated. One theory, the Accretion, or Co-Formation Theory (also known as the Condensation Theory), suggests that the Moon formed at the same time as the Earth. Simply described, as the accretion disc was spinning and materials were clumping, some clumps accreted to form the proto-planet Earth while simultaneously other clumps accreted to form the Moon. However, if the Moon formed near Earth it should have nearly the same composition, including a significant iron core. The Moon does not have a significant iron core. At almost half the density of Earth (3.3 g/cc), there is no evidence that a large iron core exists. If an iron core exists, it is very small. In addition, this theory does not have an explanation for the extra baking the lunar material must have experienced since it does not appear to have a proportional amount of water as compared with the Earth.

The second theory, the Fission Theory, describes the Moon as having formed when the hot proto-planet Earth spun so unevenly and rapidly in space that a blob flew off its surface and spun out into space. This blob eventually coalesced into the Moon. Because the composition of the Moon resembles the composition of Earth's mantle, this theory was considered a possibility because a rapidly spinning Earth could have cast off mantle material to form the Moon. However, the present-day Earth-Moon system of motion and gravitational force should contain evidence of this rapid spin and it does not. Again, this theory does not have a natural explanation for the extra baking the lunar material experienced. Interestingly, scientists who support this theory agree that the present-day Pacific Ocean basin appears to be the source of material that formed the Moon. This might make sense since the mantle of Earth is under the oceanic plates but far from the core of Earth. However, that is not enough evidence to support the Fission Theory.

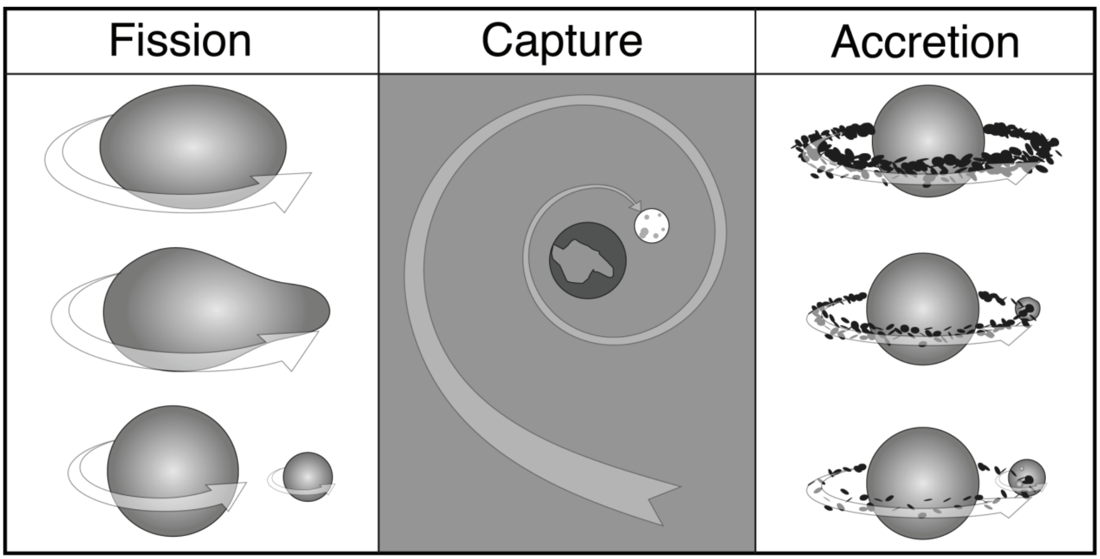


Figure 5: Illustration of three of the theories related to the origin of the Moon. (Created by Rosemary and Matthew Millham)

Another popular theory of the origin of the Moon, and hotly debated – is the Capture Theory. This theory suggests that during the violent chaos of the solar system formation, the gravitational force of proto-planet Earth captured the Moon as it was passing by too close to escape Earth's gravitational pull. To be an acceptable theory, something would have to slow the Moon down by just the right amount, at just the right time, in order for the gravitational force of the Earth to capture it. Generally, scientists are reluctant to believe that such a coincidence of time, space, speed, and direction was possible during the chaos. This theory, once again, does not have a natural explanation for the extra baking the lunar material experienced.

The theory widely accepted by lunar scientists today is the Giant Impact Theory. It suggests that a small planet, about the size of Mars, struck the Earth just after the formation of the solar system, ejecting large volumes of heated material from the outer layers of both the impactor and the early Earth. A disk of orbiting material formed from the ejected material and eventually clumped together to form the Moon in orbit around the Earth. This theory can explain why the Moon is mostly made up of rock that was baked excessively. In addition, there are pieces of evidence in many places in the solar system that support the theory that collisions were common late in the formative stages of the solar system. This theory is discussed further below.

Scientists proposed the giant impact scenario for the formation of the Moon in the 1970s. They explained that an off-center impact by a Mars-sized body with the young, hot Earth could have provided Earth with its fast initial spin and ejected enough debris into orbit to form the Moon. If the ejected materials really were from the mantles of the Earth and the impactor, this would result in the lack of a sizeable iron core in the Moon, since Earth's core was not impacted. Additionally, the energy created during the impact could account for the extra heating (or baking) of the lunar rocks that was noted during analysis of rock samples obtained by the Apollo astronauts.

However, for nearly a decade, the Giant Impact Theory was not accepted by the larger scientific community. This changed in 1984 when a conference devoted to the origin of the Moon initiated a critical comparison of the existing theories. The Giant Impact Theory emerged as the most accepted explanation mainly due to technology-enhanced models of planet formation that suggested large impacts were common events in the later stages of the formation the terrestrial planets.

It was after the Apollo astronauts brought rock samples back from the Moon and new computer models of the Earth-Moon system were developed and tested, that the Co-Formation, Fission, and Capture theories were discarded for lack of evidence and the Giant Impact Theory was accepted. Although understandable debates still exist over the question of the origin of the Moon, with enough evidence to support it, any of the four theories could be validated in the future or a completely new theory formed from new evidence.

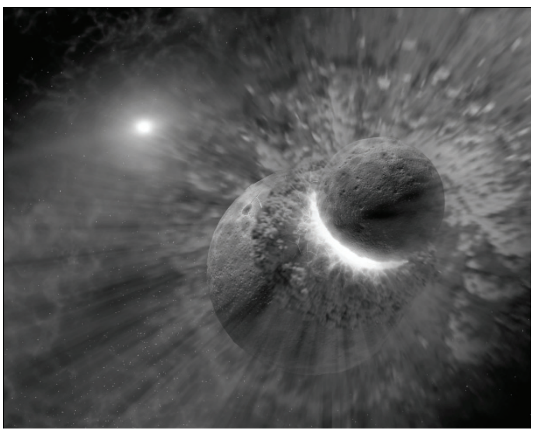


Figure 6: Artist rendition of the Giant Impact Theory, the most accepted current theory on the origin of the Moon. (Image Courtesy of NASA)

The caveat to these theories, however, is that humans were not present to witness the events that formed our solar system or the Moon. Continued research on existing data and modeling are two methods for finding answers to questions we have about the Moon and its origin. In fact, the motion of the Moon in space, phenomena such as eclipses, tides, and phases of the Moon, and many other abstract concepts, can be best understood with the model and graphic examples in this book.

Investigations - Student Observations of the Moon

Essential Question: How does observing the Moon increase our understandings about the Moon's motions in space and its surface features?

Summary for the three activities

Students will observe the Moon daily and record observations about the Moon's shape and features, the time of day, the date, and the number of degrees above the horizon that the Moon appears to be in the sky. They can illustrate the lunar surface features and label major craters, maria (Latin for *seas*), and highlands. After 2-8 weeks of observing and recording, students will compile their data into charts and summaries, compare their recordings with fellow students, analyze and interpret the results, predict what the Moon will look like, and when and where it will appear in the sky for the next 5-30 days.

Students will then compare their predictions to what actually occurs. Questions and directed and independent activities are posed throughout this investigation. The activities allow for the students to analyze and interpret recorded observations conducted over a period of weeks. Students will also create a **clinometer** to determine the altitude of the Moon above the horizon and conduct an activity on elliptical orbits.

National Science Education Standards

UNIFYING CONCEPTS AND PROCESSES (P. 104)
Evidence, models, and explanation
Change, constancy, and measurement

PHYSICAL SCIENCE (P. 154)
Motions and forces

HISTORY AND NATURE OF SCIENCE (P. 108)
Nature of scientific knowledge

Objectives
1. To engage students in observations of the Moon.
2. To develop understanding about the Moon, its motion, and its phases.

Instructional Objectives

Students will:

1. Calculate the eccentricity of ellipses and be able to explain what they are and why they are important to astronomy.
2. Collect and record information about the appearance of the Moon, including time, date, student's location, and Moon's position in degrees above the horizon.
3. Identify the patterns of shape and time associated with the movement of the Moon in its orbit around the Earth. The ability to associate the degrees above the horizon with the time of Moonrise and Moonset and the 24 hour Earth day is a skill that many interested students may want to explore.
4. Identify and illustrate the observable differences between maria, highlands, and craters on the surface of the Moon, such as color and texture.
5. Describe and explain the patterns, shapes, and phenomenon created by the Moon's proximity to the Earth and motions in the sky.
6. Discuss and compare observational findings with classmates and report the results.

Activity 1 – Drawing and Ellipse

Introduction

An ellipse is described as a closed plane curve generated by a point moving in such a way that the sums of its distances from two fixed points are equal and constant. Another way to simplify the definition of an ellipse in astronomy is to define it as any closed curved path of the orbit of one object in space about another. In fact, an ellipse is created when there are two focus (the plural is foci) points about which an orbiting body revolves. For orbiting planets and moons, one focus point is usually a star or planet. For this investigation, the Sun will represent one focus point.

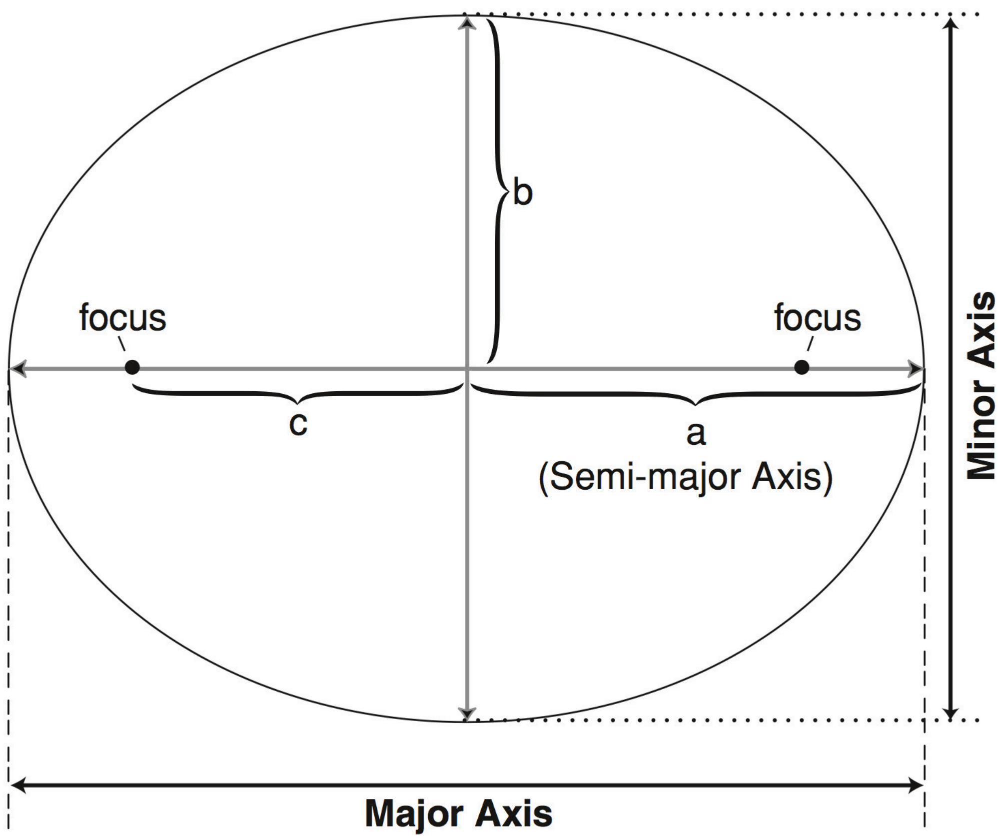


Figure 7: Above is an illustration of an ellipse. The ellipse is exaggerated. Most elliptical paths of the planets and other solar system bodies are nearly circular. This ellipse is elongated to demonstrate that an ellipse is not a perfect circle.

Note the major axis label. It indicates the longest distance, end to end, along the ellipse. The minor axis label along the right side of the diagram is the shorter distance, end to end, along the ellipse. The letter 'a' represents the semi-major axis, or half of the major axis. The letter 'b' represents half of the minor axis and is called the semi-minor axis. The letter 'c' represents the distance from the center of the ellipse to one of the focus points. Each focus point is equal distance from the center of the ellipse.

To figure out how elliptical an ellipse happens to be is determined by how far the foci are from the center of the ellipse along the major axis (see diagram above and refer to it often). The foci in the diagram are labeled. Notice that each focus is the same distance from the center of the major axis of the ellipse. The more elongated an ellipse is, the more eccentric it becomes, or the less it is a perfect circle. Eccentricity is the term used for how elongated an orbit is, which changes as the distance between the foci change. Since each focus needs to be the same distance from the center, there are many possibilities.

Essential Question: How does the position of the foci change the eccentricity of an ellipse?

Materials:
81/2” x 11” sheet of white paper and a same-sized piece of corrugated cardboard
25-cm (10-inch) length of string
Two push pins
A ruler
A pencil

Procedure

1. With the ruler and pencil, make a faint line down the center of the paper lengthwise. This line will be the major axis (long axis) of your ellipse.
2. Place the paper on the piece of cardboard. On the major axis, near the middle of the paper, insert the two pushpins about 2 centimeters apart. The pushpins represent the foci of the ellipse. One could represent the Sun, and the other could represent a point in space equidistant from the ellipse center.
3. Tie the two ends of the string together to make a loop. Place the loop around the two pushpins and pull the loop taught with your finger to make a triangle out of the string. Rotate your finger around the pushpins while keeping the string taught. You have just traced an ellipse with your finger!
4. Notice that the lengths of the two legs of the triangle extending outward from the foci change as you rotate the string, but their sum does not? That is the definition of an ellipse.
5. Now use a pencil in place of your finger and make the same motion to draw a complete ellipse. Again it is necessary to keep the string taught by pulling gently with the pencil as you rotate it around the pushpins. (Note: If the pencil extends beyond the paper, shorten the loop a little). The formula for finding the eccentricity value is:

$$\text{eccentricity} = \frac{\text{distance between foci}}{\text{length of major axis}}$$

6. Repeat the procedure with the foci set at 4, 6, 8, and 10 centimeters apart so that you end up with a family of five ellipses. Be sure to have a center point on the major axis from which to measure equally to either side the total distance between the 2 focus points. It makes a better illustration.
7. What would happen if you draw an ellipse using just one focus in the center of the major axis?
8. If your 2 focus points were at either end of the main axis, what would be the result?

Activity 2 - Making a simple clinometer

Introduction

A clinometer is a device for measuring the altitude of an object or event above the horizon. During observations of the Moon, you will need the clinometer to measure the number of degrees above the horizon that the Moon appears to be at the time you observe it. Here are the steps to make your own clinometer:

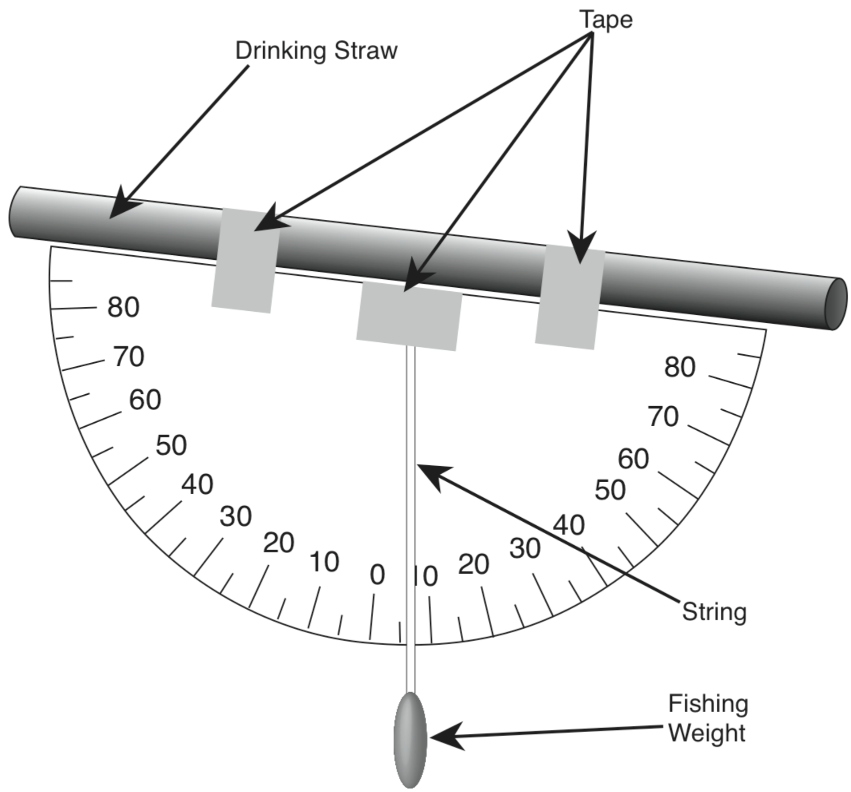
Materials:

A photocopy of a protractor, cut out, which should be about 17 cm (7 inches) long at the top.
A piece of thin cardboard a little larger than your cut out protractor photocopy
A larger diameter straw (not a bendy straw)
A piece of string about 20 cm long (about 8 inches)
Tape
A ½ inch washer or other weighty object, such as a fishing weight that can be tied to the string
Scissors

Procedure

1. Tape or glue the photocopy of the protractor cutout to the piece of cardboard. The straight edge of the protractor should be lined up with the longest side of the cardboard piece. Now cut the cardboard to fit the protractor cutout.
2. If your protractor has 90° at the top of the half circle, **renumber the lines** to match the protractor diagram below with 0° at the top of the curve (see below). This makes reading the degrees above the horizon easier later.
3. Use a pencil, awl, or large paperclip end to punch a little hole near the top edge of the protractor at the **center** of the straight edge. Since the protractors usually have a small hole in them and the teacher photocopied one for your use, there may be a little circle in the center of the straight edge of the photocopy to help you locate where the hole should be punched. Your string will need to be threaded through the hole.
4. Take the 20 cm (8") string and thread it through the little hole. Tie it off in a knot big enough so it will not go back through the hole, or tape the backside of the string to the cardboard. You need the string to hang from the hole on the protractor photocopy side of the cardboard. It should hang to the bottom edge (see diagram), but not too far below the cardboard.
5. Tie the washer or other weighted object (paperclips or fishing weights work well, too) onto the end of the string so it hangs down below the measurement lines on the protractor.
6. Now, attach the straw to the top edge of the clinometer along the same edge as the protractor's straight edge with pieces of tape. This straw is your 'view finder' when looking up at the Moon.

To use the clinometer, look through either the end of the straw until you see the Moon. The washer will swing on the protractor and the string and provide you with the degrees on the protractor. As you position the straw to look at objects above the horizon, like tree branches or a building's roof, the string will indicate an angle. This is the actual degrees above the horizon that you are viewing. It is easier to do this with one person holding the clinometer and another person reading the degrees. Practice often to become familiar with the use of this tool.



This is an illustration of a simple clinometer. (Created by Matthew and Rosemary Millham)