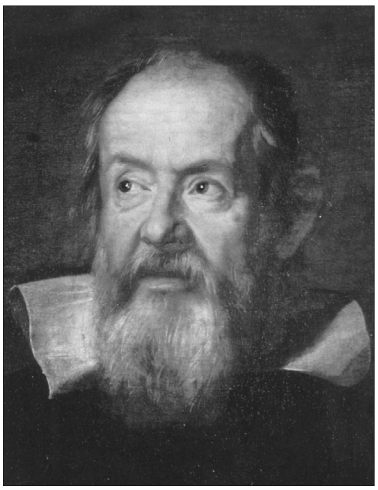
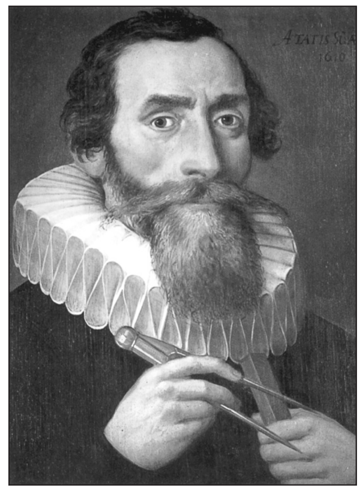
THE SOUTHWESTERN CONSORTIUM OF OBSERVATORIES FOR PUBLIC EDUCATION PRESENTS

Educational Activities for the International Year of Astronomy

The year 2009 has been designated the International Year of Astronomy (IYA) by UNESCO, the International Astronomical Union, and more than 100 countries around the world. It will be a global celebration of astronomy and its contributions to society and culture. The year celebrates the 400th anniversary of remarkable achievements made in 1609 by two astronomers, Galileo Galilei and Johannes Kepler. Activities on this poster are provided by the SCOPE observatory partners and are based on Galileo's and Kepler's work. We hope they will help you bring the IYA to life in your classroom.





Galileo Galilei

After learning of the invention of the telescope in 1609, Italian astronomer Galileo Galilei (1564-1642) decided to build one. His initial telescope magnified objects three times, but he eventually improved his design to a magnification of 20. With this better telescope, he examined the surface of the Moon that same year and found Earth-like features: craters, mountains, and smooth darker areas that he named "mare," which is the Latin word for seas. Galileo suggested that the Moon is a physical world like Earth. We still use Galileo's names for features on the Moon. To follow in Galileo's footsteps, try out our classroom activity *Observing the Moon*.

Galileo also used his telescope to discover four moons of Jupiter, and countless stars beyond what could be seen by the unaided eye. He published his first telescopic observations in his 1610 book *Sidereus Nuncius* (The Starry Messenger). Later, Galileo discovered the phases of Venus, which proved it lies between Earth and the Sun, and observed dark blotches on the Sun which we call sunspots. To learn more about sunspots, try our classroom activity *400 Years of Sunspots*.

Galileo's telescopic discoveries convinced him that Aristotle's concept of a perfect, Earth-centered universe was wrong, and that the model of a Sun-centered universe first advocated by Nicholas Copernicus in 1543 was correct.

Johannes Kepler

German mathematician Johannes Kepler (1571-1630), a contemporary of Galileo, moved to Prague in 1600 to work with astronomer Tycho Brahe. Tycho had devoted his life to making unaided-eye observations of celestial objects, and hired Kepler to use his observations of Mars to prove Tycho's own (incorrect) theory of the universe.

When Tycho died, Kepler used the thousands of accumulated astronomical observations to deduce his first two laws of planetary motion. They state that all planets orbit the Sun in elliptical paths with the Sun at one focus, and that a planet sweeps out equal areas in equal amounts of time as it moves around the Sun. Kepler published these two laws in his 1609 book *Astronomia Nova* (The New Astronomy). To help your students understand Kepler's laws, try out the classroom activity *Learning About Elliptical Orbits*.

Kepler also wrote books with tables of planetary positions (based on his laws), explanations of the Sun-centered universe theory, and more. He was the first to explain how the Moon causes tides in Earth's oceans, the first to explain how a telescope works, and the first to suggest that the Sun rotates on its axis.

SCOPE Member Observatories and Their Locations

Apache Point Observatory

Apache Point Observatory operates four telescopes: The versatile and remotely operated 3.5-meter Astrophysical Research Consortium telescope; the 2.5-m Sloan Foundation telescope; the 1.0-m New Mexico State University telescope; and the 0.5-m Astrophysical Research Consortium telescope. The public is welcome to stroll the grounds during daylight hours. While observatory buildings are not open to the public, you may wish to visit our displays at the nearby Sunspot Astronomy and Visitors Center, Sunspot, New Mexico.

www.apo.nmsu.edu
575-437-6822

Fred Lawrence Whipple Observatory

The Smithsonian Institution's Fred Lawrence Whipple Observatory is located on Mount Hopkins in the Santa Rita Range of the Coronado National Forest, south of Tucson, Arizona. The Visitors Center, at the base of Mount Hopkins, is open 8:30 a.m. to 4:30 p.m., Monday through Friday. The Observatory conducts guided tours for the general public from mid-March through November. Tours originate at the Observatory's Visitor Center. For tour details, reservations and directions, please call the Visitors Center.

www.cfa.harvard.edu/facilities/flwo/visit_center.html
520-670-5707

Kitt Peak National Observatory

The world's largest collection of optical telescopes is located high above the Sonoran Desert under some of the finest night skies in the world. Kitt Peak, on the Tohono O'odham Nation, is home to 24 optical and two radio telescopes representing eight astronomical research institutions. The Kitt Peak National Observatory Visitor Center is open to the public daily from 9 a.m. to 3:45 p.m. Guided tours are offered daily at 10 a.m., 11:30 a.m., and 1:30 p.m. and group tours are available by appointment. You can stargaze at Kitt Peak with our Nightly Observing Programs.

www.noao.edu
520-318-8732

McDonald Observatory

Join us at McDonald Observatory in the Davis Mountains of West Texas! We offer daily tours of our research telescopes, including the Hobby-Eberly Telescope — one of the world's largest. Our Frank N. Bash Visitors Center offers the Decoding Starlight exhibit, a theater that shows daily live viewings of the Sun (weather permitting), a gift shop, and a cafe. We hold public star parties every Tuesday, Friday, and Saturday night in our Telescope Park. McDonald Observatory is a research unit of The University of Texas at Austin.

mcdonaldobservatory.org
877-984-7827 or 432-426-3640

National Radio Astronomy Observatory

NRAO's Very Large Array, made famous in movies, books, documentaries and other media, has made landmark discoveries in nearly every branch of astronomy. This impressive and photogenic scientific icon, with 27 giant dish antennas rising from the high southwestern desert, is open to visitors every day from 8:30 a.m. until sunset. A self-guided walking tour, indoor displays, videos and a gift shop await the curious visitor. Bring your camera!

www.vla.nrao.edu
505-835-7410

National Solar Observatory

Take a refreshing walk through the Sacramento Mountains in the Lincoln National Forest, and explore your Sun at the Sunspot Astronomy and Visitor's Center at Sunspot, NM. Here the National Solar Observatory has a spectacular view of the Tularosa Basin, including White Sands. Dry air, isolation from major air pollution, and plenty of sunshine make this an excellent site for observing our Sun — or simply relaxing away from the rest of the world.

nsosp.nso.edu
575-434-7190

Online Resources for IYA 2009

Southwestern Consortium of Observatories for Public Education

Find connections to all member observatories of the SCOPE organization. Download a brochure. Download the activities from this poster in Adobe Acrobat PDF format, as well as other astronomy activities.

www.as.utexas.edu/mcdonald/scope

IYA International Site

Connect to the world-wide celebration for IYA. Read the latest news, watch videos, and read about projects in various countries. View the international calendar. This site includes links to IYA national web sites in more than 70 nations.

www.astronomy2009.org

U.S. Node for IYA

Find out what's happening around the country for IYA. Connect with resources geared for teachers, science centers, citizen scientists, and more. Watch videos, link to blogs and discussion forums, and see the partner organizations across the U.S. that are making IYA a reality. View the national calendar.

astronomy2009.us

NASA IYA Program

Each month throughout 2009, NASA will highlight a different area of astronomy on their IYA site. Read the features, plug into the space agency's calendar of IYA events going on nationwide, and check out a plethora of resources including podcasts and "Ask an Astrophysicist."

astronomy2009.nasa.gov

Galileo & Kepler Reference Guides

Download these comprehensive two-page references that detail books for children and adults, articles, documentaries, and web sites about Galileo Galilei and Johannes Kepler.

- astronomy2009.us/Content/Resources/IYAResource-Galileo.pdf
- astronomy2009.us/Content/Resources/IYAResource-Kepler.pdf

100 Hours of Astronomy (April 2-5, 2009)

Over three days in early April, people around the world will participate in 100 continuous hours of astronomy outreach activities including live webcasts, star parties, and more. One of the key goals of this project is to have as many people as possible look through a telescope, just as Galileo did for the first time 400 years ago. Contact your local observatory, astronomy club, or science center to see what they have planned!

www.100hoursofastronomy.org

Cosmic Diary

The Cosmic Diary aims to put a human face on astronomy, by describing what it is like to be an astronomer and a scientist. Throughout 2009, professional astronomers from five continents will blog in text and images about their life, families, friends, hobbies and interests, as well as their work, their latest research findings, and the challenges they face in their research.

www.cosmicdiary.org

Galileo Teachers Training Program

To sustain the legacy of the International Year of Astronomy past the year 2009, the International Astronomical Union plans to create the Galileo Teachers Training Program by 2012. It will be a worldwide network of certified ambassadors, master teachers and teachers, through nation-specific workshops and online training tools, to empower teachers to take advantage of the rich astronomy educational resources available today.

astronomy2009.us/education/galileoteachers

Dark Skies Awareness

The loss of a dark night sky as a natural resource is a growing concern around the globe. It impacts not only astronomical research, but also public health, ecology, safety, economics, and energy conservation. For this reason, "Dark Skies" is an IYA theme that seeks to raise awareness of the adverse impacts of excess artificial lighting on local environments by getting citizen-scientists involved in a variety of dark skies-related programs. As a means to reach this goal, six Dark Skies programs and six Dark Skies resources have been established by the IYA2009 working group. For more information, see the web sites below.

U.S. Dark Skies Programs and Resources
astronomy2009.us/darkskies/

International Dark Skies Programs
www.darkskiesawareness.org

Production and distribution of posters to Texas Science Teacher *magazine subscribers made possible by The Texas Regional Collaboratives for Excellence in Science and Mathematics Teaching, online at* thetrc.org.

LEARNING ABOUT ELLIPTICAL ORBITS

RECOMMENDED FOR GRADES 9-12

To a rough approximation, everything in the sky seems to move in circles around Earth — the Sun, the Moon, the planets, and even the stars. For thousands of years, astronomers tried to model the motion of the planets using circles or combinations of circles — partly because the circle was such a "perfect" shape. In 1543, Polish astronomer Nicholas Copernicus told us that Earth and the other planets actually orbit the Sun, and that the Moon orbits Earth. But he still described these orbits as circular. Then in 1609, German astronomer Johannes Kepler proved that the actual shape of Mars' orbit is an *ellipse*. It followed that all of the planets follow elliptical orbits around the Sun, with the Sun at one focus point.

Materials

String, 2 push pins, corrugated cardboard (~8"x11"), pencil, ruler, tape, paper

Directions

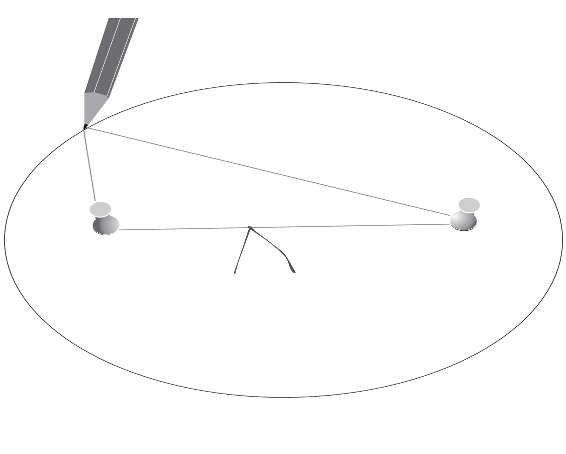
As you do the activity, write your answers for questions A through D on a separate piece of paper that you will turn in to your teacher.

Activity

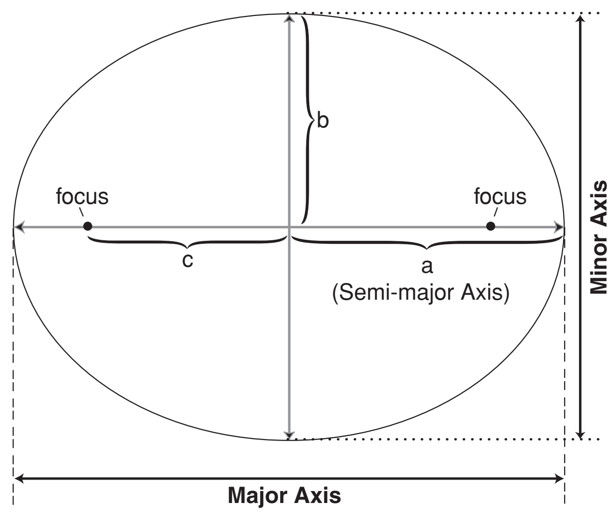
1. Tape one sheet of paper firmly to the cardboard.
2. Tie a piece of string in to a loop (~15-cm in circumference).
3. Push one pushpin into the middle of the surface of the paper.
4. Place the string around the pushpin, place the pencil inside the string and move the pencil around the pin with the string taut at all times (tracing out a circle).

A) Is this a good representation of an orbit of a planet? Why or why not? Record your answers on a separate piece of paper.

5. Place the second pushpin into the surface about 3 cm away from the first pushpin.
6. Place the string around both pushpins, place the pencil inside the string and move the pencil around the pin with the string taut at all times (tracing out an **ellipse**).
7. Move the second pushpin about another 3 cm further away from the first (6 cm total), repeat Step 6



B) Refer to the diagram below and measure the values of a, b, and c for each of the three shapes you have drawn. Record your answers on your paper.



Analysis

Eccentricity, e, indicates how an ellipse deviates from the shape of a circle:

$$e = c/a$$

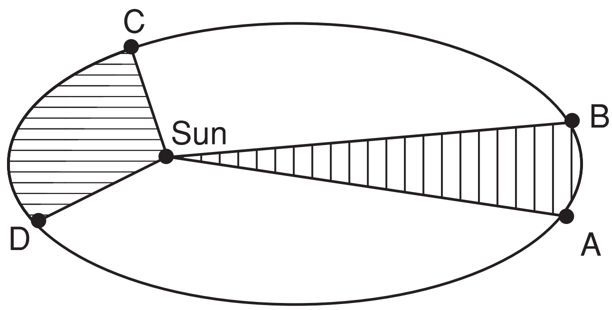
A perfect circle has an eccentricity of zero, while more and more elongated ellipses have higher eccentricities ≤1.

$$[0 \leq e \leq 1]$$

C) Record the values of e for each of your ellipses on your paper.

Extension

Kepler published his first two laws in 1609. The first law states: "The orbit of every planet is an ellipse with the Sun at one of the foci." The second explains why planets move at different speeds at different points in their orbit: "A line joining a planet and the Sun sweeps out equal areas during equal intervals of time." This is easiest to see in a diagram:



The area of A-B-Sun equals the area of C-D-Sun. Therefore, the planet is moving slower going from A to B and faster when going from C to D.

Kepler continued his work on planetary motions, and in 1619 published "Harmony of the Spheres" in which he showed that there is a relationship between a planet's distance from the Sun and the time it takes that planet to go around the Sun (its orbital period). Kepler's third law states "The squares of the orbital periods of planets are directly proportional to the cubes of the semi-major axis of the orbits.":

$$P^2 = a^3$$

(where **P** is orbital period and **a** is the semi-major axis)

This law works very well when we use years as the unit for **P** and astronomical units (AU, the Earth-Sun semi-major axis) as the unit for **a**.

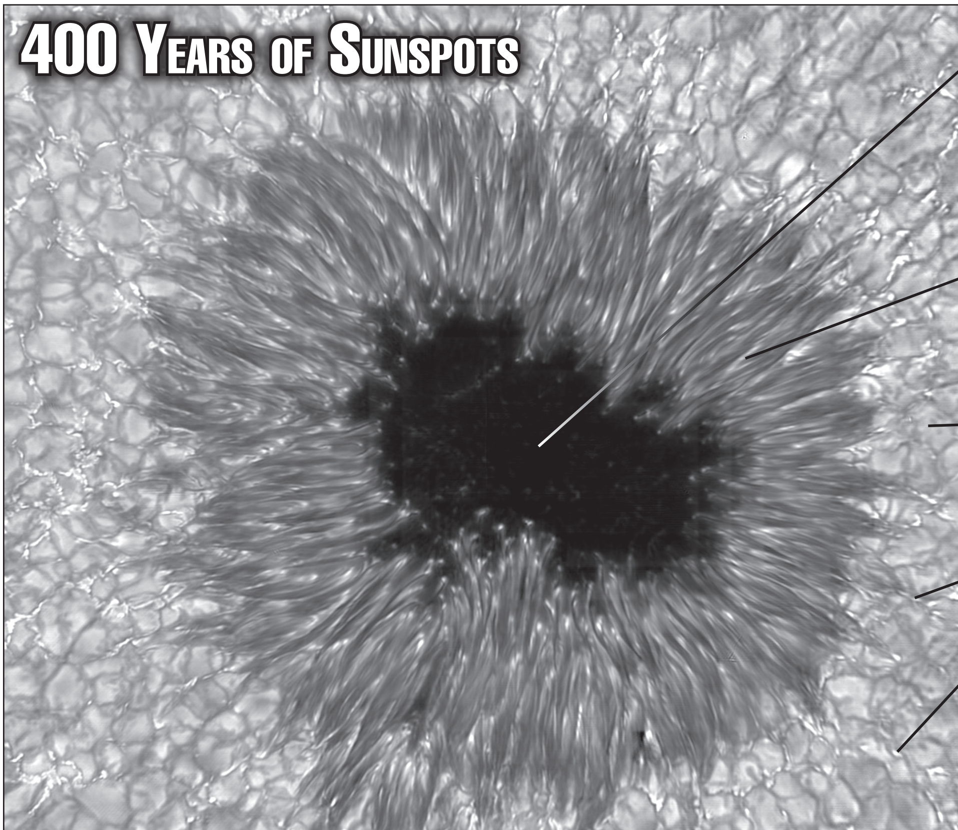
Eventually Isaac Newton (1642-1727) refined Kepler's laws so that they could be used for any orbiting objects, like comets and asteroids orbiting the Sun, moons orbiting planets, planets orbiting other stars, two stars orbiting each other — even material orbiting black holes! But it all started with the mathematical talent of Johannes Kepler.

D) The table below shows several objects in the solar system with their eccentricity and semi-major axis listed. Use the semi-major axis values to calculate the orbital period for each object (in years). Record your answers.

	Mercury	Venus	Earth	Mars	Jupiter	Saturn	Uranus	Neptune	Halley's Comet
Eccentricity	0.20563	0.00677	0.01671	0.09341	0.04839	0.05415	0.04716	0.00858	0.967
Semi-major axis (AU)	0.39	0.72	1.0	1.5	5.2	9.5	19.2	30	17.8

ANSWERS: A: *No, planet orbits are elliptical, not circular.* **B:** *(These are example measurements [in cm], allow for variation) Circle: a = 7.5, b = 7.5, c = 0; Ellipse1: a = 5.8, b = 5.6, c = 1.5; Ellipse 2: a = 4.4, b= 3.25, c = 2.*
C: *Circle: e = 0; Ellipse1: e = 0.26; Ellipse2: e = 0.68.* **D: Mercury** = *0.24 yr,* **Venus** = *0.61 yr,* **Earth** = *1 yr,* **Mars** = *1.84 yr,* **Jupiter** = *11.86 yr,* **Saturn** = *29.28 yr,* **Uranus** = *84.13 yr,* **Neptune** = *164.3 yr,* **Comet** = *75.1 yr*
Note: these values are slightly different than the real-world values due to rounding errors

400 YEARS OF SUNSPOTS



This picture of sunspot AR 10810 was taken by Friedrich Woeger, Chris Berst, and Mark Komsa using the Dunn Solar Telescope at the National Solar Observatory in Sunspot, New Mexico.

Sunspot anatomy

Umbra (Latin: shadow): Dark center, about 1000K (1,800˚F) cooler than the Sun's 5780K (9,950˚F) surface. Magnetic field up to 6,000 times stronger than Earth's.

Penumbra (Latin: Almost shadow): Flux tubes where magnetism leaks to rest of solar surface.

Granule: Cells of hot gas circulating in the Sun. Granules are the size of Texas to the size of Alaska!

Lane: Cool gas circulating back to interior.

Bright point: Tiny area heated by intense magnetic fields.

One of the great discoveries that Galileo and his contemporaries made with their telescopes is that the Sun does not have a perfectly smooth surface, and that it changes over time. Although sunspots had been recorded as early as 28 BC, until Galileo's time, people thought they were caused by Earth's imperfect atmosphere. Systematic observations by Galileo, Johannes and David Fabricius, and Christoph Scheiner showed that these spots were associated with the Sun. In the 1800s, we learned that spot numbers rise and fall about every 11 years. In 1908, George Ellery Hale discovered that they are caused by intense magnetism.

How big are sunspots? Try this simple scaling exercise to find out.

A circle has 360 degrees. Each degree can be divided into 60 minutes of arc, and each minute of arc can further be divided into 60 seconds of arc (sometimes called arc-seconds, denoted by the same symbol we use for inches: "). We know that the Sun is 109 times wider than Earth, and has an average apparent or angular size of 1,920 arc-seconds (1,920"). Answer the following in your notebook:

a. What would be the apparent or angular size of an Earth-size object in arc-seconds if we viewed it against the Sun?

b. This image covers a diameter 56 arc-seconds wide. How much wider than Earth is it?

c. Measure the size of the sunspot image. What would be the size of Earth on this scale? How accurate would it be to use a ping-pong ball with a diameter of 40mm to represent Earth at this scale? (You could color one green and blue and hang it in front of the image for comparison.)

d. How wide would this sunspot image have to be to match the scale of a 30-cm (12-inch) classroom globe?

This isn't the biggest spot ever recorded. Often they are much bigger and appear in clusters of many spots together.

Answers:

a. Sun diameter/Earth-Sun ratio = 1,920"/109 = 17.6"

b. Image size/Earth size = relative size 56"/17.6" = 3.18 wider

c. The picture is printed to be 127 mm. Image width/Earth relative size = model size 127 mm/3.18 = 40 mm (rounded off) — about the size of a ping-pong ball. It is a good representation.

d. Calculate the ratio class globe/"ping-pong Earth" x image size = (300 mm/40 mm) x 127 mm = 7.5 x 127 mm = 953 mm (38 inches, rounded off)

Observing the Moon

Does the Moon always look the same? Does its surface look different at different times? Did it look the same 400 years ago as it does now? What will your students say when you ask them these questions?

Many students are aware that the Moon goes through phases, but except for the "man in the Moon" — which many admit they have a hard time seeing — they probably haven't thought about the surface of the Moon and how we view it from Earth. In fact, until Galileo studied it in 1609, not many people tried to explain the variations on the Moon's surface. In this activity, students examine the lunar surface and make detailed observations of the Moon at different points in its cycle, just as Galileo did 400 years ago.

Materials

Clear skies, Notebook, Soft pencil, Binoculars

Preparation

First, figure out when you can see the Moon. You will need to see it on two separate days (about 5-10 days apart). Use a sky almanac or a calendar to find the Moon's phase on the day you will carry out this activity. The outdoor part of this activity requires good weather.

In choosing a day, keep these tips in mind:

- If you need to observe the Moon at the same time of day (or night) for each day, make sure you choose an appropriate phase for the first observation.
- For morning hours, it is best to begin two or three days before the last quarter phase.
- For evening hours, it is best to begin two or three days before the first quarter phase.

Once you know the Moon's phase, the chart provided here will help you decide the best time of day (or night!) for lunar viewing.

Activity

Draw two 10-cm circles in your observing notebook. List the time, date, sky conditions, and location. Indicate the phase of the Moon within your circle. Now, sketch in the light and dark areas. A soft pencil works best. Some students like to smudge their lines to show light and dark. Repeat the activity using binoculars; they will allow you to see more detail. At another phase (five to ten days later), repeat the activity.

Analysis *(Questions for the students to answer)*

Compare the unaided-eye and binocular drawings done on the same date with each other. What details are visible? Can you identify any features from the lunar map? Now compare the drawings from one date to the other. What changed?

Near full Moon, patterns of dark and light on its surface are easy to distinguish. The "maria" — smooth, almost crater-free regions on the Moon — are easiest to see then.

During crescent or quarter phases, the craters and mountains cast distinct shadows and become more noticeable, especially near the terminator (the edge of the shadow).

Some students may mention that the Moon changes colors. It actually doesn't — the colors are due to the effects of our own atmosphere, not anything intrinsic to the Moon.

Extension

For an in-class activity, make craters by dropping marbles into a deep basin of flour sprinkled with dry chocolate mix. You should get nice craters with elevated edges, and some with a series of splashed out materials centered on the crater. In a darkened room, shine a flashlight onto the cratered surface and show how the angle of the flashlight determines the length of the shadows.

As a math extension, calculate the angle between the Sun and Moon for different phases. As an English extension, write a poem about the Moon.

Phase	New	First Quarter	Full	Last Quarter
Rise	Sunrise	Noon	Sunset	Midnight
Highest in Sky	Noon	Sunset	Midnight	Sunrise
Set	Sunset	Midnight	Sunrise	Noon

Features of the Lunar Landscape