# Table of Contents

<table>
<thead>
<tr>
<th>Topic</th>
<th>Pages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Be an Astronomer</td>
<td>1</td>
</tr>
<tr>
<td>Observing the Moon</td>
<td>2, 3, 4</td>
</tr>
<tr>
<td>Origin of the Moon</td>
<td>5, 6</td>
</tr>
<tr>
<td>Interpreting the Moon</td>
<td>7, 8</td>
</tr>
<tr>
<td>Moon from Earth and Space</td>
<td>9, 10</td>
</tr>
<tr>
<td>The Moon in Human Imagination</td>
<td>11</td>
</tr>
<tr>
<td>Moons of the Solar System</td>
<td>12</td>
</tr>
<tr>
<td>Moon in Human History</td>
<td>13, 14</td>
</tr>
<tr>
<td>Geology of the Moon</td>
<td>15, 16</td>
</tr>
<tr>
<td>Exploration</td>
<td>17</td>
</tr>
<tr>
<td>Lunar Eclipse</td>
<td>18</td>
</tr>
<tr>
<td>Key Terms</td>
<td>19</td>
</tr>
<tr>
<td>Resources</td>
<td>20</td>
</tr>
</tbody>
</table>
Be an Astronomer

You can start at anytime, check the moon calendar of when the moon will be rising and setting. Once you know when to observe, make a plan to go outside and look in the sky to find the moon. This guide along with links to astronomical websites will help you to know when, where and how to observe the moon.

Our lunar neighbour rises in the east, travels across the sky from east to west and then sets below the western horizon. You look to the southern sky and imagine a line in an arch across the sky. This imaginary line in the sky is called the ecliptic and it is the path traveled by the sun during the day as it moves from east to west in an arch. This arch is lower in the winter and higher in the summer. Along the ecliptic is also where you will find the moon in the sky.

Once you have located the moon, take your time and observe and think about what do you see. Identify the shape of the whole moon, then look at the colours and texture of the surface of the moon. You can take a picture or draw a picture that captures what you observe. Record the drawing or picture in table found in the Moon Worksheet.

Here is a list of your Be an Astronomer activities:

▷ Learn skills on how and when to observe the moon.

▷ Carefully observing the sky and locating the moon over a set period of time.

▷ Thinking about what you are observing.

▷ Recording what you see with a picture or drawing.

▷ Sharing your new knowledge by completing the activities.
The Moon is the closest celestial neighbour to planet Earth. Humans have observed the Moon for thousands of years. Many cultures have learned to use the Moon to measure time. Nature uses certain phases of the Moon to govern animal activity. You will get to know the moon and its phases as you observe throughout the lunar month.

The Moon is one of the simplest objects to observe. You can watch how the Moon’s phase changes over time and its counter clockwise orbit around Earth. There is no need for specialized equipment. The best method is to look with your unaided eye and a good lunar map. Observing the Moon can be done from anywhere including in the city. If you have binoculars or a small telescope you can observe a closer and more detailed view of lunar features.

**Moon Light**

Moonlight is not generated by the Moon but is reflected sunlight. Even though a full Moon is very bright, the surface reflects only between 3 and 12 percent of the sunlight. The lunar surface material determines how much sunlight is reflected. For example, lava fields will appear darker while ejecta rays near craters are brighter. The speed of light is approximately 300,000 meters per second. Sunlight takes about eight minutes to reach Earth and and only 1.3 seconds to reach your eye from the Moon Sunlight reflected from Earth to the Moon is called Earth shine and is seen on the unlit side of the Moon.
Here are 10 suggestions to observe the Moon.

1. You can use your eyes, binoculars or a small telescope on a tripod.

2. Finding the principal features is not hard, so you can learn observing skills.

3. The Moon is bright, offering plenty of detail visible to the unaided eye or even in small telescopes or binoculars.

4. Look along the terminator between day and night for the most detail.

5. Look for shadows cast on crater floors by the crater’s walls.

6. Look for mountain peaks on the night side that are close and high enough above the terminator to catch sunlight.

7. You can observe the Moon from anywhere – a dark sky location is not required.

8. You can observe the Moon throughout the year.

9. Use the Moon workbook to record the phase of the moon you observe. Ensure that you go out at the same time each night throughout the lunar month so you can compare the shape and location of the moon as it changes.

10. Here is where you can find updated information on where and when you can observe the moon.
    
    [https://www.timeanddate.com/worldclock/Canada/Calgary](https://www.timeanddate.com/worldclock/Canada/Calgary)
Photographing the Moon

Taking photographs of the Moon can be rewarding. Images can be created with any type of camera. Even today’s mobile device cameras have options for nighttime photography. If you can use a tripod for your camera that helps to keep the camera steady while you are taking your moon pictures.

Start experimenting by using the camera’s built-in automatic setting. This will allow you to change the various settings and see the effects. Review the image details on the camera noting the shutter speed (how long the shutter is open), ISO (film speed), and aperture (how much light the lens lets in). Share your lunar pictures in the Moon Workbook.

Drawing the Moon

You can create amazing pencil on paper sketches of the moon. Observe the moon, start with with drawing the oval of the whole moon. Observe the light and dark areas and try your best to fill in your oval with the darker and lighter regions.

Learn more about how to draw the moon [https://rasc.ca/carol-lakomiaks-astrosketching-tutorials-moon](https://rasc.ca/carol-lakomiaks-astrosketching-tutorials-moon)

Moon on black sketching paper, with white, gray, and black pastels.
by Eric Klaszus
Origin of the Moon

The moon is made up of bits of the earth. One theory on how the moon formed is called Collision. As the earth was forming over six billion years ago a large asteroid smacked into the earth causing pieces of the earth off the surface and fall into orbit around the earth. Gravity gathered the bits of earth together forming a new mass we call the moon.


Natural satellite

The moon is a mass and mass has gravity. The size of mass equals the amount of gravity it holds. The earth is also a mass with gravity. The earth is six times larger than the moon so it holds six times more gravity. The force of gravity holds the two masses in orbit around each other.

The Moon - Earth’s Satellite [https://www.youtube.com/watch?v=JsZhoQG2tiE](https://www.youtube.com/watch?v=JsZhoQG2tiE)

Gravity and Orbit

Gravity has fascinating effects on both the earth and the moon as these two masses orbit each other. The gravitation effect of the moon upon the earth is a tidal effect. As the moon orbits around the earth its gravity pulls and tugs on the earth which causes the motion of earth’s oceans water. The regular and predictable motion of the moon in its orbit creates consistent tides on earth. High and low tides are accurately forecast due to this regular motion. The earth also has a gravitation effect on the moon. Earth’s gravity pulls and tugs on the moon and that force causes a squeeze and expansion of the moon. The shape shifting of moon causes the moon to slowly move away from the earth by 3.8 cm each year.

Animation of the Earth Moon tidal lock orbit - NASA [https://svs.gsfc.nasa.gov/4709](https://svs.gsfc.nasa.gov/4709)
What is the Moon Made of?

A tool called a spectrograph is used by astrophysicists to analyze or learn more about the light reflected by the moon. As the light passes through a spectrograph it creates a spectral analysis. From this data, astrophysicists can determine what is the composition of the moon. The spectra reveals that the moon is rocks and iron. The crust of the moon is composed mostly of oxygen, silicon, magnesium, iron, calcium, and aluminum. There are also trace elements like titanium, uranium, thorium, potassium and hydrogen. A spectrograph gives astrophysicists the tools to discover what a distant object like the moon is made of by not visiting the moon but by collecting the reflected light emitted from the moon that reaches the earth.

The spectra below was acquired using the RAO’s echelle spectrograph.

The pink curve is the spectrum of the sun reflected from a dark maria region of the moon.

The blue curve is the spectrum of the sun reflected from a bright highland region of the moon.

By carefully comparing these two spectra the composition of moon can be explored. This portion of the sun’s spectrum is in the blue region, as depicted by the color strip at the top (bottom) of the image. The most prominent absorption feature is the Beta-line in the Balmer series of the element Hydrogen.
Interpreting the Moon

Moon in Song

The moon is part of the regular cycles of life on earth. We see the moon in the night and sometimes during the day. How and when we observe the moon depends on its phase. Humans and animals and insects and birds express themselves with sound and song. Celebrating the moon is a wonderful inspiration for music or a song.

Moon in Poetry

Exploring the moon in verse has a long tradition. The beauty of the moon in a dark sky is expressed by poets and shows a connection between life on earth and its stellar neighbour. Humans did not visit the moon until 1969, so up until that time, poets would imagine visiting the moon and describe it with poetic language.

The stars about the lovely moon
Fade back and vanish very soon,
When, round and full, her silver face
Swims into sight, and lights all space.

Sappho, Ancient Greek Poet
620 BCE–550 BCE
Moon in Art

Art that depicts the night often includes a moon in the sky. Paintings or drawings can symbolize the night or a mysterious mood. The phase of the moon and the type of light reflects the astronomical features of the sky.

The painter Vincent Van Gogh painted ‘Starry Night’ in 1889. This oil painting portrays the motion and distortion of the atmosphere. When you observe the moon just like Vincent, you are looking through earth’s atmosphere. Your view of the moon will be slightly blurry because of the atmosphere. This effect also causes the stars to appear as if they are twinkling. Vincent captured this effect and energy on canvas over one hundred years ago.

https://www.moma.org/collection/works/79802
Moon from Earth & Space
Apparent Versus Actual Motion

We observe the motion of the moon from earth. Standing on earth and watching the moon we see it rise in the east, move across the sky and set in the west. This is due to the motion of the earth as it spins on its axis. We also observe that the moon appears at different places in the sky each day as it moves through the eight phases of the lunar month.

Lunar Month

The Moon's sidereal orbital period or month is 27.3 days. Sidereal is the period the time it takes for the moon to complete a 360 degree orbit around the earth, when measured against fixed stars.

A syndic month is the period of time between full moon to full moon, which averages at 29 days 12 hours 44 minutes 3 seconds.

This means that there are 13 lunar months per calendar year. A sidereal orbit is the real or true orbit of the moon. While syndic orbit is how the moon’s orbit appears to us on earth.

Phases of the Moon

The moon as viewed from earth appears to move through eight phases throughout the lunar month. Each phase is described by when the moon appears in the sky and how much of the moon is visible. The lunar month starts with a new moon, then the moon appears to get bigger to a full moon phase, then less is visible until the return to the new moon. Check out the diagram below and notice the shape of the moon during each phase.

The graphic below demonstrates phases of the moon and was created and photographed by Simon Poole, RASC

Moon libation animation
https://www.youtube.com/watch?v=GYE2P7BWBA
The Moon in Human Imagination

Cinema Moon

In the early days of cinema one of the first science fiction movies was about visiting the moon. In 1902, a French film called ‘A Trip to Moon’ was created by director George Méliès. A fantasy story about adventurers building a rocket and flying to the moon, where they discover alien moon creatures.

Science Fiction Moon

Storytelling related to science and the future is called Science Fiction. In 1865, writer Jules Verne published “From Earth the Moon”. In this story, he speculates that a cannon could create enough force to send a spacecraft to the moon. Another idea in the story involves weightlessness that people exploring the moon might experience. The stuff of imagination over one hundred years ago. Today we know that rockets can take people to the moon. Rockets are equipped with engines that create enough thrust to escape the gravitational pull of the earth which is 11 km per sec. Humans on the moon do not experience total weightlessness because the moon as a mass holds gravity. But what is correct is that the moon is smaller than the earth, has less gravity and so humans who have visited the moon can move in different ways than on earth.
Moons in the Solar System

The earth has one moon, but there are hundreds of moons in our solar system. Planets Venus and Mercury have no moons. Mars has two small moons called Deimos and Phobos. The most massive moon of the entire solar system is Ganymede, which has a diameter of 5269 kilometres. The strange moon Hyperion is the least dense moon at 0.5 grams per cubic centimetre. Triton is a very cold place with a surface temperature hovering around -235° celsius. On the other end of the temperature spectrum is Io which is the hottest moon with temperatures of more than 1,200 degrees celsius. Speeding around the planet Neptune is the fastest moon at 32,000 kilometres per hour. We cannot observe the smallest moons from earth. We learn about these tiny moons from space probes that fly near their host planet. Technology continually discovers new moons. Today we have observed 214 moons, but we may learn about more new moons with new observations.
Moon in Human History

The moon has been observed, measured and depicted throughout human history. We can look at architecture, objects or documents to understand what scientists of history understood about the moon.

The regular and predictable movement of the moon in the sky acts as a precise instrument for counting and marking time. Capturing the regular patterns of the lunar month is evident in the ancient paintings found in the Lascaux Caves in France, dated at over 15,000 years old, these paintings depict the moon as it moves through eight phases with 29 renderings of the moon.

https://sservi.nasa.gov/articles/oldest-lunar-calendars/

Counting and carefully following lunar cycles was a way that ancient peoples could identify the changing of the seasons. These two oracle bones have markings that are dated to the Shang Dynasty c. 1800 - 1200 BCE. The bones were found in China and their markings follow a solar year which is 365 1/4 days. A lunar month is marked at 29 1/2 days as well as depicting the eight phases of the lunar cycle.

http://www.webexhibits.org/calendars/calendar-chinese.html
**Quantifying the Moon**

**Mapping the Moon**
One of the first scientific maps of the moon. Created by astronomer Giovanni Domenico Cassini in 1670. Cassini viewed the moon through a telescope and painstakingly drew the details of the lunar surface.

**Imaging the Moon**
Astronomer Thomas Harriot created this first drawing of the moon through a telescope. In 1609, the only way to create an scientific image of the moon was to draw an rendering from careful and precise observations.

**Modeling the Moon**
Modeling is attempting to recreate the shape, motion and physical processes of natural objects in relation to one another to demonstrate how they work. A scale model of the moon and the sun can demonstrate how they orbit in space.

A Philosopher Lecturing on the Orrary by Joseph Wright, 1766
Geology of the Moon

The layers and details of scientists understanding of the geological history of the moon is traced through the maps created by astronomers. The lunar maps can tell what the astronomers were able to discern or observe, but also how well their technology was able to detect the details of the geological features. The current geological surveys of the moon tell us about the surface of moon and also down through its layers to the core.

When you are an astronomer and observing the moon start by looking for the large darker areas. These are lava fields known as ‘Maria’ which is Latin for ‘Seas’. Craters, caused by asteroid or comet impacts, have many interesting features such as central peaks, lava flooded floors, or smooth or ridged crater walls. Some craters with flooded floors have smaller craters caused by newer impacts.
Geological Facts and Features

More than one million craters on the moon are over one kilometre wide.

Impact Craters – asteroid impact sites on the surface of the moon.

The shape, size and features of an impact crater tells us about the asteroid that hit the surface, its speed and size its shape.

Two main types of impact craters are classified as simple or complex.

Complex Craters - lots of features including terraces, central peaks, and multiple rings.

We can trace back to a period of heavy bombardment around 3.9 billion years ago in the history of the solar system.

Maria – large smooth regions created by basalt lava flows of the early moon.

Rilles – long and narrow valleys on the moon.

Domes – are a shield type of volcano that was formed in the early formation of the moon.

Wrinkle ridges – thin ridges found on the maria that formed when the basalt lava cooled.

Grabens – trough valley created during a cooling period on the lunar surface.

Exploration

The serious plans to send humans to the moon begin in the 1950s. The two space organizations in the Soviet Union and the United States of America developed plans for space exploration. In 1959, the first satellite – Sputnik was launched by the Soviet Union. The first person in space was Soviet Cosmonaut Yuri Gagarin in 1961. NASA was the first to send a manned spacecraft to orbit around the moon. Over fifty years ago, a crew of three astronauts Neil Armstrong, Buzz Aldrin and Michael Collins flew the Apollo 11 mission. They reached the moon and Armstrong was the first human to walk on the lunar surface.

Missions to the Moon

The NASA Lunar website provides a list of all of the missions to the moon. Humans, robots, cameras and mirrors have all been launched to the moon. Space probe robots were sent to the moon to accomplish missions including learning the chemical, mineral, atmospheric and geologic details of the moon. Watch for new missions, like Artemis.

https://moon.nasa.gov/exploration/moon-missions/
Lunar Eclipse

The moon orbits around the earth and the earth orbits the sun. The orbital plane shifts which means that from earth we observe a fascinating natural phenomenon called eclipses. Due to the regular and observable shifts in the orbits and where we see the moon and sun in the sky. At times we observe these masses line up and create eclipses. A lunar eclipse is when we can observe the shadow of the earth on the face of the moon. For a period of time, usually two to three hours, we will see the moon darken in colour and take on a brownish orange shade. A lunar eclipse only occurs during the full moon phase. Please see diagram below which demonstrates how the sun and moon align.

https://airandspace.si.edu/multimedia-gallery/web11715-2010640jpg
Key Terms

Asteroid - a rocky mass in the solar system that orbits the sun.

Astronomy – the study and observation of celestial objects and understanding what they are and how they move.

Crater – a depression in a surface of the moon that was created by an asteroid impact or possibly a volcanic eruption.

Gravity – the force of attraction that brings two masses together, all things with mass hold gravity.

Light – electromagnetic energy that is emitting from the sun and is reflected by the moon.

Moon – a natural satellite that orbits a planet.

Planet – celestial objects that formed from a planetary disc of dust, gas and rocks that orbit around a star.

Orbit – motion of a mass around another mass.

Space - the area outside of the earth’s atmosphere.

Space Probe - a robot launched into space to collect data and images.

Sun – the star at the center of our solar system that creates its own energy at its core through a process of nuclear fusion.

Telescope – tool that collects light and brings that light to a focus to observe and study light from celestial objects.

Tidal lock – two masses orbiting one another.
Cool and Amazing Resources

NASA Artemis Mission
https://www.nasa.gov/specials/artemis/

NASA Impact Craters
https://www.nasa.gov/stem-ed-resources/impact-craters.html

Lunar and Planetary Institute
https://www.lpi.usra.edu/education/explore/shaping_the_planets/impact-cratering/

European Space Agency Guide to the Moon
https://www.esa.int/Science_Exploration/Human_and_Robotic_Exploration/ESA_s_guide_to_the_Moon

Oxford University - Human Depiction of the Moon

PBS Investigating the Moon’s Apparent Movement | Lesson Plan

RASC - Calgary Centre Lunar Eclipses
https://calgary.rasc.ca/downloads/Observing_and_Understanding_the_Moon's_Phases_and_Eclipses.pdf

Canada’s Role in Moon Exploration