Chapter 5
The Moon
I. Lunar Myths
II. Physical Characteristics of the Moon
III. Lunar Eclipses
IV. Solar Eclipses
V. Tides
VI. Tidally-Locked Orbit
Moon Trivia

• Has the simple name ‘Moon’. It was the only known moon in the solar system until 1610.

• The name Monday is derived from Old English (around 1000 AD) *mōnandæg* (literally meaning “Moon's day”).

• The Moon is not round, but egg shaped with the large end pointed towards earth.
Moon Trivia

• Blue Moons aren’t blue; and Black Moons aren’t there.

• With a circumference of 6785 miles, it would take 4 days traveling at 70 mph to circumnavigate the Moon.

• Twelve Americans have been the only men to walk on the Moon; the last one in 1972.

• Americans drove 3 Moon Buggies across the surface of the Moon for a distance of 57 miles.*
"Lunatic" is an informal term referring to people who are considered mentally ill; conditions once called lunacy.

The word derives from *lunaticus* meaning "of the moon" or "moonstruck".
Lunacy – Moon Madness

The full Moon has been linked to:

- Outbursts of Psychologically Challenged Adults
- Lycanthropy (Werewolves)
- Vampirism
- Alcoholism
- Sleep Walking
- Violence in Prisons
- Psychiatric Admissions
- Agitated Behavior by Nursing Home Residents
- Assaults
- Gunshot Wounds
- Suicide
- Major Disasters
- Casino Payout Rates
- Assassinations
- Kidnappings
Ivan Kelly, James Rotton and Roger Culver (1996) examined over 100 studies on lunar effects and concluded that the studies have failed to show a reliable and significant correlation.

There is no relationship between the appearance of a full moon and deviant behavior…
Lunacy – Moon Madness

- The fact that the human body is mostly water largely contributes to the notion that the Moon should have a powerful effect on the human body and therefore an effect on behavior.
- It is claimed by many that the Earth and the human body both are both 75% water.
- This is false.
- Seventy-five percent of the *surface* of the Earth is water.
- Furthermore, the Moon only affects *unbounded* bodies of water, while the water in the human body is bounded.
The Moon

Trip to the Moon, 1902 French silent film
Pareidolia

Pareidolia is the imagined perception of a pattern or image where it does not actually exist.
Pareidolia

• The Man in the Moon is an example of *pareidolia*.
• Culture dictates the imagery found on the surface of the Moon.
Pareidolia – The Rabbit
Your Pareidoloria
• Our Moon is a very large object. Indeed, the Earth-Moon "system" could be properly thought of as a "double planet system".
• No other pair in the Solar System are so close in size.
# Moon Surface Temperatures

<table>
<thead>
<tr>
<th></th>
<th>Highest Temperature °F</th>
<th>Lowest Temperature °F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moon</td>
<td>243</td>
<td>–272</td>
</tr>
<tr>
<td>Earth</td>
<td>134</td>
<td>–126</td>
</tr>
</tbody>
</table>
The Moon: Size

• Earth’s moon is the 5th largest moon in the solar system.
• Three of the Galilean Moons are larger than the Moon.

![Moon comparison diagram](image_url)
The Moon: Size

Diameter of Moon is 3,476 km

Width of USA is 4,180 km
The Moon: Size
The Moon: Size
The Moon: Size
Surface area of the Moon is equal to 4.8 times the landmass of mainland USA.

4.8 mainland USAs = 1 moon
The Moon: Mass

The Moon has $7.3477 \times 10^{22}$ kg of mass.

It would take $81\frac{1}{2}$ Moons to equal the Earth’s mass.

The Moon has $7.3477 \times 10^{22}$ kg of mass
The Moon: Gravity

- The gravitational force on the Moon is defined by Newton’s Universal Law of Gravitation
- Gravity is a force that is mutually exerted by all celestial objects.
- The Moon pulls on the Earth with an equal amount of gravitational force.
The Moon: Gravity

- Objects on the surface of the Moon are subject to the same law of gravity.
- The mass and diameter of the Moon dictates the amount of gravitational pull the Moon has on an object.
The Moon: Gravity

The gravitational force on the Moon is 1/6 that of Earth.

A 100 pound girl would weigh 17 pounds.
A 185 pound boy would weigh 31 pounds.
The Moon: Distance from Earth

The Moon is approximately 384,400 km (238,857 miles) from the Earth.

It took Apollo 11 three days to reach the moon in 1969 (average speed of 3,300 mph).

A radio message will take 1.26 seconds to reach the Moon.
Kepler’s First Law states that orbits are ellipses and not circular.

**Apogee** is the furthest point from the Earth, 406,300 km.

**Perigee** is the closest point to the Earth, 356,300 km.
Kepler’s First Law states that orbits are ellipses and not circular.

**Apogee** is the furthest point from the Earth, 406,300 km.

**Perigee** is the closest point to the Earth, 356,300 km.
The Moon: Distance from Earth

Full Moons of 2008
by Bill Bradley

APOGEE MAY 19, 2008
23:04 EDT
distance: 252,480 miles
angular diameter 29° 23.9’

PERIGEE DECEMBER 12, 2008
20:20 EST
distance: 221,575 miles
angular diameter 33° 30.0’
The Moon: Distance from Earth

Super Moon
05.05.2012

Micro Moon
28.11.2012
The Moon appears to be 12% smaller at its apogee than when it is at its perigee.
The Super Moon of March 19, 2011 (right), compared to an average full moon of December 20, 2010.
### The Moon: Super Moons

<table>
<thead>
<tr>
<th>Year</th>
<th>Date</th>
<th>Perigee Distance</th>
<th>Time from Full</th>
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<tbody>
<tr>
<td>2018</td>
<td>January 1</td>
<td>21:56UT</td>
<td>356,565km</td>
</tr>
<tr>
<td>2019</td>
<td>January 21</td>
<td>19:59UT</td>
<td>357,344km</td>
</tr>
<tr>
<td>2019</td>
<td>February 19</td>
<td>9:07UT</td>
<td>356,761km</td>
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<tr>
<td>2020</td>
<td>March 10</td>
<td>6:34UT</td>
<td>357,122km</td>
</tr>
<tr>
<td>2020</td>
<td>April 7</td>
<td>18:10UT</td>
<td>356,908km</td>
</tr>
</tbody>
</table>
The closest full moon of the 21st century will fall on December 6, 2052 (356,425 km).
The Moon: Barycenter

The center of the Moon's orbit is not in the center of the Earth.

The Earth and Moon revolve around a common point called the barycenter.
The Moon: Barycenter

- The barycenter is located INSIDE the Earth.
- About 1707 kilometers below its surface. Or, about 1060 miles.
The boundary between the illuminated part of the Moon's disc and the dark part is called the **Terminator**.

The circular edge of the **Limb**.

The points where the limb and terminator join (roughly at the lunar poles) are the **Cusps**.
Fission Hypothesis

- The Moon was once part of the Earth and somehow separated from the Earth early in the history of the Solar System.
- The present Pacific Ocean basin is the most popular site for the part of the Earth from which the Moon came.
Moon’s Origin: Erroneous Hypothesis

Fission Hypothesis

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- The present Pacific Ocean basin is the most popular site for the part of the Earth from which the Moon came.
Moon’s Origin: Erroneous Hypothesis

Fission Hypothesis – the Moon was flung off the surface of the Earth.

Pros:
   Density of Moon similar to that of the outer layers of the Earth

Cons:
   • Moon should be orbiting along Earth's equator; it's not.
   • Composition of Moon rocks dissimilar to that of the Earth's surface.
   • Earth would have to have been spinning extremely fast
Moon’s Origin: Erroneous Hypothesis

Capture Hypothesis – The Moon was formed somewhere else, and was later captured by the gravitational field of the Earth.

Pros:
It's not possible

Cons:
The mass of the Earth isn’t great enough to capture an object the size of the Moon
Condensation hypothesis
The Moon and the Earth condensed together from the original nebula that formed the Solar System.
Moon’s Origin: Erroneous Hypothesis

Condensation hypothesis – The Moon and the Earth condensed together from the original nebula that formed the Solar System.

Pros:
Lots of material around in the early solar system to accrete

Cons:
• The Earth and Moon have different compositions.
• Earth-Moon system has too much angular momentum compared to other planets.
Moon’s Origin

The Large-Impact Hypothesis

A large planetesimal hits Earth, ejecting material which forms the Moon
Moon’s Origin

The Large-Impact Hypothesis

A large planetesimal hits Earth, ejecting material which forms the Moon. The planetesimal injects its iron core into the Earth.
Moon’s Origin

The Large-Impact Hypothesis

Pros:
• Collisions happened
• Explains lack of volatiles in Moon
• Explains Moon’s lack of an Iron core
• Explains tilt of the Earth's axis.
Moon’s Origin

The Large-Impact Hypothesis

Cons:
• To get material past the Earth's Roche limit, the impactor needs more angular momentum than is now in the Earth-Moon system.
• Why just one moon?
Elements on the Surface of the Moon & Earth

- Calcium
- Iron
- Aluminum
- Silicon
- Oxygen

Concentrations

- Earth
- Lunar Lowland
- Lunar Highland
Impact cratering involves high velocity projectiles collide with the surface of the Moon.

Impact craters are not unique only to the Moon

Manicougan Crater, Quebec, Canada. A 100 kilometer diameter crater. Approximately 212 million years old.
Impact Craters

Impact cratering involves high velocity projectiles colliding with the surface of the Moon. Impact craters are not unique only to the Moon. Manicougan Crater, Quebec, Canada, a 100 kilometer diameter crater, approximately 212 million years old.

Orbiting 400 kilometers above Quebec, Canada, planet Earth, the International Space Station Expedition 59 crew captured this snapshot of the broad St. Lawrence River and curiously circular Lake Manicouagan on April 11.
Impact Craters

Impact cratering involves high velocity projectiles collide with the surface of the Moon.

Impact craters are not unique only to the Moon. Clearwater Lakes, Canada. A pair of impact craters – 20 and 13 km in diameter. Approximately 290 million years old.
Impact cratering involves high velocity projectiles collide with the surface of the Moon.

Impact craters are not unique only to the Moon. Barringer Crater, Arizona. A 1.2 km diameter crater. 49,000 years old.
Impact Craters

Impact cratering involves high velocity projectiles collide with the surface of the Moon.

Impact craters are not unique only to the Moon.

One of Saturn's smallest moons, Mimas has a crater is 65 km in diameter. Mimas’s radius is 198 km.
Impact Craters

• The current story of the surface of the Moon is that of a heavily cratered surface.
• From the nature and appearance of these craters we can piece together part of the story of the Moon's history.
Impact Craters

• **Davy** is a small lunar crater that is located on the eastern edge of the Mare Nubium.
• A small chain of craters formed from a small comet or meteorite broke apart prior to impact.
Impact Craters

A relatively young impact crater from which radiate streaks of material thrown out during the collision that created the crater.

Crater Tycho with rays
Impact Craters

A relatively young impact crater from which radiate streaks of material thrown out during the collision that created the crater.
Impact Craters

• The Copernican system (crater and rays) is a mere 800 million years old.
• Material ejected from it forms a bright system of rays out to a distance of 800 km from the crater.
The Seas and Ocean of the Moon

- The lunar maria are large, dark, basaltic plains on Earth's Moon, formed by ancient volcanic eruptions.
- They were dubbed maria, Latin for "seas", by early astronomers who mistook them for actual seas.
The Seas and Ocean of the Moon

They are darker than the "highlands" as a result of their iron-rich compositions which reflect less light.
The Seas and Ocean of the Moon

- The maria cover about 16 percent of the lunar surface, mostly on the near-side visible from Earth.
- The few maria on the far-side are much smaller, residing mostly in very large craters where only a small amount of flooding occurred.
The Seas and Ocean of the Moon

The traditional nomenclature for the Moon also includes:

1. *oceanus* (ocean)
2. 22 marias (seas)
3. 20 lacus (lakes)
4. 11 sinus (bays)
5. 3 paludes (marshes)
Highlands

- The highlands are generally about 4 to 5 km (2.5 to 3 miles) above the average lunar surface elevation.
- The highlands are older than the maria; therefore, are more heavily cratered.
The image is a cylindrical projection of the Moon's surface.
The Seas and Ocean of the Moon

- **Mare Frigoris**: sea of cold
- **Mare Imbrium**: sea of rains
- **Plato (crater)**
- **Copernicus (crater)**
- **Mare Tranquillitatis**: sea of tranquility
- **Mare Serenitatis**: sea of serenity
- **Mare Crisium**: sea of crises
- **Oceanus Procellarum**: ocean of storms
- **Mare Humorum**: sea of moisture
- **Mare Nubium**: sea of clouds
- **Tycho (crater)**
- **Mare Foecunditatis**: sea of fertility
- **Mare Nectaris**: sea of nectar
- **Mare Vaporum**: sea of vapours
The Sea of Tranquility

This Mare has a slight bluish tint due to higher metal content in the basaltic soil or rocks. This mare also served as the landing site for the Apollo 11 lunar module, the first manned landing on the Moon.
The Sea of Serenity

*Mare Serenitatis,* this mare also served as the landing site for the Apollo 17 lunar module, the final manned landing on the Moon.
The Mare Imbrium (its Latin name) is one of the largest mares on the moon. This mare also served as the landing site for the Apollo 15 lunar module.
The Ocean of Storms

Like all lunar maria, Oceanus Procellarum was formed by ancient basaltic flood volcanic eruptions that covered the region in a thick, nearly flat layer of solidified magma.
The Eastern Sea

The Mare Orientale is a giant impact crater, roughly 1000 km. The dark region at upper right is Oceanus Procellarum on the Moon's near side.
The Far Side of the Moon

• The far side of the Moon is the lunar hemisphere that is permanently turned away from the Earth.
• It is NOT the DARK SIDE of the Moon – we don’t see it because of the Moon’s slow rotation.
The Far Side of the Moon

The rugged terrain is distinguished by a multitude of crater impacts, as well as relatively few lunar maria.
The Moon Illusion is an optical illusion in which the Moon appears larger near the horizon than it does while higher up in the sky.
The Moon Illusion

• One of the main theories which explains this illusion is known as the Ponzo Illusion.
• Named after Mario Ponzo who demonstrated it in 1913 - suggests that the mind judges the size of an object based on its background.
The Moon Illusion

These rats change size when depth cues are added...
The Moon Illusion
The Moon Illusion
The Moon Illusion
One of the main theories which explains this illusion is known as the Ponzo Illusion. Named after Mario Ponzo who demonstrated it in 1913 - suggests that the mind judges the size of an object based on its background.
The Moon Illusion is also caused by light being refracted (bent) as it passes through the atmosphere. This is similar to what occurs with a setting sun.
The Moon Illusion
• Visual albedo is the amount of light reflected by a celestial body (planet, moon, asteroid, etc.).
• Albedo is measured as the percentage of light bouncing from the surface of the body.
• Stars do not have albedo, they radiate light (produce their own light).
Moon Shine

• The Moon reflects only 0.12 of the light that strikes it.
• The Moon appears brighter during a Full Moon because more of its light is reflected directly towards us.

Earth’s Albedo is 0.30
Moon Shine

- The Moon reflects only 0.12 of the light that strikes it.
- The Moon appears brighter during a Full Moon because more of its light is reflected directly towards us.
The Phases of the Moon

From Earth, we see different portions of the same “face” of the Moon’s surface lit by the sun, causing the phases of the Moon.
The Phases of the Moon

- Lunation is the time for one lunar phase cycle.
- Approximately 59% of the Moon’s surface is visible from the Earth
The Phases of the Moon

The New Moon

• The Moon is between the Sun & the Earth; therefore, it isn’t entirely visible (nor completely invisible)
The Phases of the Moon

Waxing Crescent

wax – to increase gradually in size
First Quarter Moon

- A quarter moon occurs when we see the Moon half illuminated by the Sun, and half enshrouded in darkness.
- Rises at Noon
- Sets at Midnight
The Phases of the Moon

gibbous – a characteristic of convexity (being convex) – having a hump, humpback
The Phases of the Moon

**Full Moon**
- Rises at Dusk
- Sets at Dawn
The Phases of the Moon

Waning Gibbous

wane – to gradually decrease in size
The Phases of the Moon

Third Quarter Moon
• A quarter moon occurs when we see the Moon half illuminated by the Sun, and half enshrouded in darkness.
• Rises at Midnight
• Sets at Noon
The Phases of the Moon

Waning Crescent
The Phases of the Moon
The Motion of the Moon

Sidereal Period and Synodic Period

- Earth's orbit
- New Moon
- New Moon
- Sidereal month completed when Moon was here
The Motion of the Moon

The Moon orbits Earth in a \textbf{sidereal period} of 27.32 days.

Sidereal Period - the time required for the moon to reach the same position in the sky relative to the fixed stars.
The Motion of the Moon

The Moon orbits Earth in a **synodic period** of 29.53 days.

**Synodic period** - the time required for the Moon to reach the same position relative to the Sun.
The Motion of the Moon

- The Moon’s Orbit is at a 5° tilt to the ecliptic.
- Because of this tilt approximately 59% of the Moon’s surface is visible from the Earth.
Shadows – A Few Terms

The **umbra** (Latin for "shadow") is the darkest part of the shadow.
Shadows – A Few Terms

The **penumbra** (from the Latin *paenes* "almost, nearly" and *umbra* "shadow") is the region in which only a portion of the object causing the shadow is obscuring the light source.
The **antumbra** (opposite or negative) is the region from which the occulting body appears entirely contained within the disc of the light source.
Conditions for Eclipses

This can occur only when the Sun, Earth, and Moon are aligned exactly, or very closely so, with the Earth in the middle.
A lunar eclipse is an eclipse which occurs whenever the Moon passes behind the Earth such that the Earth blocks the Sun’s rays from striking the moon.
Conditions for Eclipses

The type and length of an eclipse depend upon the Moon’s location relative to its orbital nodes.
Conditions for Eclipses

The type and length of an eclipse depend upon the Moon’s location relative to its orbital nodes.
Conditions for Eclipses

The **lunar nodes** are the orbital nodes of the Moon, that is, the points where the orbit of the Moon crosses the ecliptic.
Lunar Eclipse
Lunar Eclipse

Total Lunar Eclipse as seen from the Moon.

Notice the change in the color of the Earth’s atmosphere.
Lunar Eclipse

During a total eclipse, the moon has a faint, red glow, reflecting sunlight scattered in Earth’s atmosphere.

2nd period
Lunar Eclipse

A prism can be used to break light up into its constituent spectral colors (the colors of the rainbow).
Lunar Eclipse

Atmospheric refraction causes blue light to bend towards the Earth. Red light is bent to a lesser degree. During a Lunar Eclipse, the Moon passes through the area where the red light is refracted.
Lunar Eclipses: 2017-2020

• The following slide lists the lunar eclipses that are visible only to Charleston.
• There are several more that will occur, but will not be visible from Charleston.
## Lunar Eclipses: 2017-2020

<table>
<thead>
<tr>
<th>Dates</th>
<th>Eclipse</th>
<th>Type at max</th>
<th>Visibility in Charleston</th>
<th>In Charleston</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feb 10, 2017</td>
<td>Lunar</td>
<td>Penumbral</td>
<td>Penumbral</td>
<td></td>
</tr>
<tr>
<td>Jan 31, 2018</td>
<td>Lunar</td>
<td>Total</td>
<td>Partial</td>
<td></td>
</tr>
<tr>
<td>Jan 20 – 21, 2019</td>
<td>Lunar</td>
<td>Total</td>
<td>Total</td>
<td></td>
</tr>
<tr>
<td>Jul 4 – 5, 2020</td>
<td>Lunar</td>
<td>Penumbral</td>
<td>Penumbral</td>
<td></td>
</tr>
<tr>
<td>Nov 30, 2020</td>
<td>Lunar</td>
<td>Penumbral</td>
<td>Penumbral</td>
<td></td>
</tr>
</tbody>
</table>
Lunar Eclipses: January 21

<table>
<thead>
<tr>
<th>Event</th>
<th>Time in Charleston*</th>
<th>Visible</th>
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</thead>
<tbody>
<tr>
<td>Penumbral Eclipse begins</td>
<td>Jan 20 at 9:36 pm</td>
<td>Yes</td>
</tr>
<tr>
<td>Full Eclipse begins</td>
<td>Jan 20 at 11:41 pm</td>
<td>Yes</td>
</tr>
<tr>
<td>Maximum Eclipse</td>
<td>Jan 21 at 12:12 am</td>
<td>Yes</td>
</tr>
<tr>
<td>Full Eclipse ends</td>
<td>Jan 21 at 12:43 am</td>
<td>Yes</td>
</tr>
<tr>
<td>Penumbral Eclipse Ends</td>
<td>Jan 21 at 2:48 am</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Duration: 5 hours, 11 minutes
Duration of Totality: 1 hour 1 minute
Solar Eclipses

A solar eclipse occurs when the moon passes between the Sun and the Earth so that the Sun is fully or partially covered. This can only happen during a new moon.
Solar Eclipses

From the Earth, the angular diameter of the Sun is about the same as that of the Moon.
Solar Eclipses
A total eclipse occurs when the Sun is completely obscured by the Moon. During the eclipse, totality (the Moon completely obscures the Sun) is visible only from at most a narrow track on the surface of the Earth.
Solar Eclipses

A *partial eclipse* occurs when the Sun and Moon are not exactly in line and the Moon only partially obscures the Sun. This phenomenon can usually be seen from a large part of the Earth outside of the track of an annular or total eclipse.
Solar Eclipses
Solar Eclipses

Annular Eclipse
From within the antumbra, the Sun appears larger than the Moon. The Sun appears as a very bright ring, or annulus, surrounding the outline of the Moon.
Solar Eclipse
Solar Eclipses: 2014-2020

Approximately 1 total solar eclipse per year

<table>
<thead>
<tr>
<th>Calendar Date</th>
<th>Eclipse Type</th>
<th>Geographic Region of Eclipse Visibility</th>
</tr>
</thead>
<tbody>
<tr>
<td>2016 Sep 01</td>
<td>Annular</td>
<td>Atlantic, c Africa, Indian</td>
</tr>
<tr>
<td>2017 Feb 26</td>
<td>Annular</td>
<td>Pacific, Chile, Argentina, Atlantic, Africa</td>
</tr>
<tr>
<td><strong>2017 Aug 21</strong></td>
<td><strong>Total</strong></td>
<td><em>n Pacific, U.S., s Atlantic (afternoon in Charleston)</em></td>
</tr>
<tr>
<td>2018 Feb 15</td>
<td>Partial</td>
<td>Antarctica, s S. America</td>
</tr>
<tr>
<td>2018 Jul 13</td>
<td>Partial</td>
<td>s Australia</td>
</tr>
<tr>
<td>2018 Aug 11</td>
<td>Partial</td>
<td>n Europe, ne Asia</td>
</tr>
<tr>
<td>2019 Jan 06</td>
<td>Partial</td>
<td>ne Asia, n Pacific</td>
</tr>
<tr>
<td>2019 Jul 02</td>
<td><strong>Total</strong></td>
<td>Pacific, Chile, Argentina</td>
</tr>
<tr>
<td>2019 Dec 26</td>
<td>Annular</td>
<td>Saudi Arabia, India</td>
</tr>
<tr>
<td>2020 Jun 21</td>
<td>Annular</td>
<td>c Africa, s Asia, China, Pacific</td>
</tr>
<tr>
<td>2020 Dec 14</td>
<td><strong>Total</strong></td>
<td>s Pacific, Chile, Argentina, s Atlantic</td>
</tr>
</tbody>
</table>
Lunar topography has considerable relief because of the presence of mountains, craters, valleys, etc. The irregularities of the lunar limb profile can obscure light from planets and the Sun.
As the moon "grazes" by the Sun during a solar eclipse, the rugged lunar limb topography allows beads of sunlight to shine through in some places, and not in others. This effect is called **Baily's beads** in honor of Francis Baily who first provided an explanation of the phenomenon in 1836.
The **diamond ring effect** is a feature of total solar eclipses. Just before the sun disappears or just after it emerges from behind the moon, the rugged lunar limb topography allows beads of sunlight to shine through.
The Tides

Tides are caused by the difference of the Moon’s gravitational attraction on the water on Earth.
The Tides

Tides are caused by the difference of the Moon’s gravitational attraction on the water on Earth.
The Tides

The gravitational forces act on the Earth's volume in two ways:

1. They stretch the Earth along the Earth-Moon line.
2. They move materials, especially fluid materials like water, toward the Earth-Moon line.

Both of these effects contribute to two tidal bulges on opposite sides of the Earth.
Earth’s tidal bulges are slightly tilted ahead of the Moon’s orbit because the Earth rotates faster than the Moon’s orbit.
The Tides

The bulge stays slightly ahead of the Moon

1st period

12:24 hour tidal period
Spring and Neap Tides

The Sun is also producing tidal effects, about half as strong as the Moon.

- Near Full and New Moon, those two effects add up to cause spring tides.
- Results in *higher* than normal high tides and *lower* than normal low tides.
Spring and Neap Tides

• Near first and third quarter, the two effects work at a right angle, causing *neap tides*.

Results in *lower* than normal high tides and *higher* than normal low tides.
Spring and Neap Tides

Spring Tides

Solar Tides
Lunar Tides
The tidal range is the vertical difference between the highest high tide and the lowest low tide.

Charleston has a 6 foot tidal range.
The world's largest tidal differential occurs in the Bay of Fundy in Eastern Canada, where the sea level changes by up to 17 meters (55 feet) during the day.
The Tidal Range

The world's smallest differential occurs in the Gulf of Mexico and the Caribbean, where the sea level changes as little as 20 centimeters (8 inches) during the day.
The Earth also exerts tidal forces on the moon’s rocky interior.

- It is rotating with the same period around its axis as it is orbiting Earth (tidally locked).
- Imagine children holding hands and playing Ring Around the Rosies.
Tidal Effect on Moon’s Orbit

Gravitational force pulls the moon slightly forward along its orbit. The end result is a kind of tidal 'sling shot' effect that pulls the moon forward in its orbit.
The faster a satellite travels, it must move into a higher orbit. Therefore, the Moon is moving away from the Earth by 3.8 centimeters/year (1½ inches/year).
The friction between the water and the Earth’s crust is slowing the rotational speed of the Earth. The Earth’s day is slowing at the rate of 2.2 seconds every 100,000 years.
Tidal Effect on Moon’s Orbit

Approximately, 620 million years ago: the day was 21.9 hours, and there were 400 solar days per year.
Tidal Effect on Moon’s Orbit

Even at that, it will take 140 million years before the earth's rotation slows enough to necessitate a 25-hour day.
The End is Near…
Once in a Blue Moon

- The most likely origin of Blue Moon comes from the Middle English word *bellewe*, which, in addition to "blue", can mean "betray".
- Months were determined from full moon to full moon.
- The extra full moon upset the liturgical calendar of public worship within the Catholic Church.
Once in a Blue Moon

• A Blue Moon is a second full Moon during a single month.
• Most years have twelve full moons that occur approximately monthly.
• Each solar calendar year contains roughly eleven days more than the lunar year of 12 lunations.
• The extra days accumulate, so every two or three years there is an additional full moon.
Once in a Blue Moon

The Moon does not become blue during a Blue Moon.
Once in a Blue Moon

The following years/months will contain an additional lunation:

- 2020: October 1 & October 31
- 2023: August 1 & August 31
Black Moon

- The absence of a full moon in a calendar month.
- The sydonic period of the Moon is 29.53 days and February lasts 28 days.
- It is possible for there to be no full moon during February.
- The next Black Moon will occur in February 2037.
Earth’s “Other” Moon

A quasi-satellite is an object in a specific type of co-orbital configuration with a planet where the object stays close to that planet over many orbital periods.
Earth’s “Other” Moon

A quasi-satellite's orbit around the Sun takes exactly the same time as the planet's, but has a different eccentricity (usually greater), as shown in the diagram on the right.
Earth’s “Other” Moon

When viewed from the perspective of the planet, the quasi-satellite will appear to travel in an oblong retrograde loop around the planet.
Earth’s “Other” Moon

• Discovered on October 10, 1986, 3753 Cruithne is an asteroid in orbit around the Sun.
• It is only a quasi-satellite
• Its orbit takes it close to orbit of Mercury and outside the orbit of Mars
• Cruithne is approximately 5 kilometers (3.1 mi) in diameter
Earth’s “Other” Moon

• Its closest approach to Earth is 12 million kilometers (approximately 30 times the distance between Earth and the Moon)
• Its orbital path and Earth’s do not cross, and its orbital plane is currently tilted to that of the Earth by 19.8°
• There is no danger of a collision with Earth for millions of years.
Earth’s “Other” Moon

It takes 770 years for the series to complete a horseshoe-shaped movement around the Earth.
Earth’s “Other” Moon

- Six more resonant near-Earth objects (NEOs) have since been discovered.
- These include:
  1. (164207) 2004 GU9
  2. (277810) 2006 FV35
  3. 2010 SO16
  4. 2014 OL339
  5. 2002 AA29
  6. 2003 YN107
Earth’s Trojan

- A Trojan asteroid essentially shares its orbit with a planet and has an almost identical orbital period.
- When viewed from the planet, the asteroid appears to oscillate about one of the stable points in front of, or behind, the planet.
Earth’s Trojan

- After years of searching, astronomers have finally found an Earth Trojan asteroid, 2010 TK7.
- The asteroid, called 2010 TK7, is nearly 1,000 feet across and currently leading the Earth by about 50 million miles.
Earth’s Trojan

- Asteroid 2010 TK7 remains on the leading side of the Earth as both go around the Sun at almost precisely the same average rate.
- Because its orbit is both quite eccentric and inclined to the Earth's orbit, the asteroid appears to loop around an empty point in space.