Chapter 23: The Sun-Earth-Moon System

Section 1: Earth

Section 2: The Moon – Earth’s Satellite

Section 3: Exploring Earth’s Moon
Chapter 23: The Sun-Earth-Moon System
Section 1: Earth

Grade 6 Earth Science
Mr. Norton
Section 1: Earth

Section Objectives

1. Examine Earth’s physical characteristics.

2. Differentiate between rotation and revolution.

3. Discuss what causes seasons to change.
People used to think that Earth was flat and at the center of the universe. It is a round, three-dimensional object called a sphere. Its surface is the same distance from its center at all points. Some common examples of spheres are basketballs and tennis balls.
Aristotle, a Greek astronomer and philosopher who lived around 350 B.C., suspected that Earth was spherical. He observed that Earth cast a curved shadow on the Moon during an eclipse.
In addition to Aristotle, other individuals made observations that indicated Earth’s spherical shape.
Early sailors, for example, noticed that the tops of approaching ships appeared first on the horizon and the rest appeared gradually, as if they were coming over the crest of a hill.
Additional Evidence

• Sailors also noticed that as they sailed north or south, the North Star moved higher or lower in the sky.

• Today, most people know that Earth is spherical and all objects are attracted by gravity to its center.
Rotation

- Earth’s **axis** is the imaginary vertical line around which Earth spins.
- This line cuts directly through the center of Earth.
- The poles are located at the north and south ends of Earth’s axis.
- The spinning of Earth on its axis, called **rotation**, causes day and night to occur.

Section 1: Earth
Rotation

- As Earth rotates, you can see the Sun come into view at daybreak.
- Earth continues to spin, making it seem as if the Sun moves across the sky until it sets at night.
- During night, your area of Earth has rotated so that it is facing away from the Sun.
Rotation

- Earth continues to rotate steadily, and eventually the Sun comes into view again the next morning.
- One complete rotation takes about 24 h, or one day.
- Earth completes about 365 rotations during its one year journey around the Sun.

### Physical Properties of Earth

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diameter (pole to pole)</td>
<td>12,714 km</td>
</tr>
<tr>
<td>Diameter (equator)</td>
<td>12,756 km</td>
</tr>
<tr>
<td>Circumference (poles)</td>
<td>40,008 km</td>
</tr>
<tr>
<td>Circumference (equator)</td>
<td>40,075 km</td>
</tr>
<tr>
<td>Mass</td>
<td>$5.98 \times 10^{24}$ kg</td>
</tr>
<tr>
<td>Average density</td>
<td>5.52 g/cm$^3$</td>
</tr>
<tr>
<td>Average distance to the Sun</td>
<td>149,600,000 km</td>
</tr>
<tr>
<td>Period of rotation (1 day)</td>
<td>23 h, 56 min</td>
</tr>
<tr>
<td>Period of revolution (1 year)</td>
<td>365 days, 6 h, 9 min</td>
</tr>
</tbody>
</table>
Magnetic Field

- Scientists hypothesize that the movement of material inside Earth’s core, along with Earth’s rotation generates a magnetic field.
- This magnetic field is much like that of a bar magnet. Earth has a magnetic field with north and south poles.
- When you sprinkle iron shavings over a bar magnet, the shavings align with the magnetic field of the magnet.

Section 1: Earth
Magnetic Field

• Earth’s magnetic field is similar—almost as if Earth contained a giant bar magnet.

• Earth’s magnetic field protects you from harmful solar radiation by trapping many charged particles from the Sun.
Magnetic Axis

• Earth’s magnetic axis, the line joining its north and south poles, does not align with its rotational axis.
• The magnetic axis is inclined at an angle of 11.5° to the rotational axis.
• If you followed a compass needle, you would end up at the magnetic north pole rather than the rotational north pole.
Magnetic Axis

• The location of the magnetic poles has been shown to change slowly over time.
• The magnetic poles move around the rotational (geographic) poles in an irregular way.
• This movement can be significant over decades.
• Many maps include information about the position of the magnetic north pole at the time the map was made.

Section 1: Earth
What causes changing seasons?

Orbiting the Sun

• A **revolution** is Earth’s yearly orbit around the Sun.

• Just as the Moon is Earth’s satellite, Earth is a satellite of the Sun.

• If Earth’s orbit were a circle with the Sun at the center, Earth would maintain a constant distance from the Sun, but this is not the case!

Section 1: Earth
What causes changing seasons?
Orbiting the Sun

• Earth’s orbit is an **ellipse**—an elongated, closed curve.

• The Sun is not centered in the ellipse, the **distance** between Earth and the Sun changes during the year.
What causes changing seasons?

Orbiting the Sun

- Earth gets closest to the Sun—about 147 km away—around January 3.

- The farthest Earth gets away from the Sun is about 152 million km away. This happens around July 4 each year.

Section 1: Earth
What causes changing seasons?  
**Orbiting the Sun**

- Even though Earth is closest to the Sun in January, the change in distance is small.
- Earth is exposed to almost the same amount of Sun all year.
- But the amount of solar energy any one place on Earth receives varies greatly during the year.

**Section 1: Earth**
A Tilted Axis

- Earth’s axis is tilted 23.5° from a line drawn perpendicular to the plane of its orbit.
- It is this **tilt** that causes seasons.
- The number of daylight hours is greater for the hemisphere that is tilted toward the Sun.
A Tilted Axis

• The hemisphere that is tilted toward the Sun receives more hours of daylight than the hemisphere that is tilted away from the Sun.

• The longer period of sunlight is one reason why summer is warmer than winter, but it is not the only reason.
Radiation from the Sun

• Earth’s tilt also causes the Sun’s radiation to strike the hemispheres at different angles.
• Sunlight strikes the hemisphere tilted towards the Sun at a higher angle, that is, closer to 90 degrees, than the hemisphere tilted away.
• It receives more total solar radiation than the hemisphere tilted away from the Sun, where sunlight strikes at a lower angle.

Section 1: Earth
Radiation from the Sun

• Summer occurs in the hemisphere tilted toward the Sun when its radiation strikes Earth at a higher angle and for longer periods of time and the sun appears **high** in the sky.
• The hemisphere receiving less radiation experiences winter.

Section 1: Earth
Solstices

- The **solstice** is the day when the Sun reaches its greatest distance north or south of the equator.
- In the northern hemisphere, the **summer** solstice occurs on June 21 or 22, and the **winter** solstice occurs on December 21 or 22.

Section 1: Earth
Solstices

• In the southern hemisphere, the winter solstice is in June, and the summer solstice is in December.
• Summer solstice is about the longest period of daylight of the year.
• After this, the number of daylight hours become less and less, until the winter solstice, about the shortest period of daylight of the year.
• Then the hours of daylight increase again.
Equinoxes

- An equinox occurs when the Sun is directly above Earth’s equator.
- Because of the tilt of Earth’s axis, the Sun’s position relative to the equator changes.
- Two times each year the Sun is directly over the equator, resulting in the spring and fall equinoxes.
- At an equinox the Sun strikes the equator at the highest possible angle, 90°.
Equinoxes

- During an equinox, the number of daylight hours and nighttime hours is nearly equal all over the world.
- Also at this time, neither the northern hemisphere nor the southern hemisphere is tilted toward the Sun.
Equinoxes

• In the northern hemisphere, the Sun reaches the spring equinox on March 20 or 21, and the fall equinox occurs on September 22 or 23.

• In the southern hemisphere, the equinoxes are reversed. Spring occurs in September and fall occurs in March.
Earth Data Review

- Earth is a sphere that rotates on a tilted axis.
- This rotation causes day and night. Earth’s tilted axis and its revolution around the Sun cause the seasons.
- On Earth revolution takes one year.

Section 1: Earth
Question 1

Which term describes the shape of Earth?

A. axis
B. ellipse
C. sphere
D. waxing
The answer is C.

Earth is a round, three-dimensional object and casts a curved shadow on the Moon during an eclipse.
Question 2

The imaginary vertical line around which Earth spins is its __________.

A. axis
B. ellipse
C. longitude
D. meridian
The answer is A.

This line cuts directly through the center of Earth.
Question 3

The spinning of Earth on its axis is its ____________.

A. equinox
B. orbit
C. revolution
D. rotation
The answer is D.

One complete rotation takes 24 hours.
Chapter 23: The Sun-Earth-Moon System
Section 2: The Moon – Earth’s Satellite

Grade 6 Earth Science
Mr. Norton
Section 2: The Moon – Earth’s Satellite

Section Objectives

1. Identify phases of the Moon and their cause.
2. Explain why solar and lunar eclipses occur.
3. Infer what the Moon’s surface features may reveal about its history.
Motions of the Moon

• Just as Earth rotates on its axis and revolves around the Sun, the Moon rotates on its axis and revolves around Earth.

• The Moon’s revolution around the Earth is responsible for the changes in its appearance.

Section 2: The Moon – Earth’s Satellite
Motions of the Moon

• The Moon’s rotation takes 27.3 days—the same amount of time it takes to revolve once around Earth.

• Because these two motions take the same amount of time, the same side of the Moon always faces Earth.

Section 2: The Moon – Earth’s Satellite
Reflection of the Sun

• The Moon seems to shine because its surface reflects sunlight.

• Just as half of Earth experiences day as the other half experiences night, half of the Moon is lighted, while the other half is dark.

• As the Moon revolves around Earth, you see different portions of its lighted side, causing the Moon’s appearance to change.

Section 2: The Moon – Earth’s Satellite
Phases of the Moon

- **Moon phases** are the different forms that the Moon takes in its appearance from Earth.

- The phase depends on the relative positions of the Moon, Earth, and the Sun.
Phases of the Moon

• A **new moon** occurs when the Moon is between Earth and Sun.

• During a new moon, the lighted half of the Moon is facing the Sun and the dark side faces Earth.

• The Moon is in the sky, but it cannot be seen.
Waxing Phases

• After a new moon, the phases begin waxing.
• **Waxing** means that more of the illuminated half of the Moon can be seen each night.
• About 24 h after a new moon, you can see a thin slice of the Moon.
• This phase is called the **waxing crescent**.

Section 2: The Moon – Earth’s Satellite
Waxing Phases

• About a week after a new moon, you can see half of the lighted side of the Moon, or one quarter of the Moon’s surface. This is the first quarter phase.
Waxing Phases

• When more than one quarter is visible, it is called **waxing gibbous** after the Latin word for “humpbacked.” A **full moon** occurs when all of the moon’s surface facing Earth reflects light.
Waning Phases

• After a full moon, the phases are called waning.
• When the Moon’s phases are waning, you see less of its illuminated half each night.
• **Waning gibbous** begins just after a full moon.

Section 2: The Moon – Earth’s Satellite
Waning Phases

- When you can see only half of the lighted side, it is the **third-quarter phase**.
- The Moon continues to appear to shrink.
- **Waning crescent** occurs just before another new moon.

Section 2: The Moon – Earth’s Satellite
Waning Phases

- It takes about 29.5 days for the Moon to complete its cycle of phases.
- Recall that it takes about 27.3 days for the Moon to revolve around Earth.
- The discrepancy between these two numbers is due to Earth’s revolution. The roughly two extra days are what it takes for the Sun, Earth, and Moon to return to their same positions.
What causes an eclipse?

• **Eclipses** occur when Earth or the Moon temporarily blocks the sunlight from reaching the other.
• Sometimes, during a new moon, the Moon’s shadow falls on Earth and causes a solar eclipse.
• During a full moon, Earth’s shadow can be cast on the Moon, resulting in a lunar eclipse.
What causes an eclipse?

• An eclipse can occur only when the Sun, the Moon, and Earth are lined up perfectly.

• Because the Moon’s orbit is not in the same plane as Earth’s orbit around the Sun, lunar eclipses occur only a few times a year.
What causes an eclipse?

• During a total solar eclipse, many animals act as if it is nighttime.
• Cows return to their barns and chickens go to sleep.
Eclipses of the Sun

• A solar eclipse occurs when the Moon moves directly between the Sun and Earth and casts its shadow over part of Earth.
Eclipses of the Sun

• The darkest portion of the Moon’s shadow is called the **umbra**.

• A person standing within the umbra experiences a total solar eclipse.

• During a total solar eclipse, the only visible portion of the Sun is a pearly white glow around the edge of the eclipsing Moon.
Eclipses of the Sun

- Surrounding the umbra is a lighter shadow on Earth’s surface called the penumbra.
- Person’s standing in the penumbra experience a partial solar eclipse. A total solar eclipse is only visible on a small area of Earth.
- WARNING: Regardless of which eclipse you view, never look directly at the Sun. The light can permanently damage your eyes.

Section 2: The Moon – Earth’s Satellite
Eclipses of the Moon

- When Earth’s shadow falls on the Moon, a **lunar eclipse** occurs.
- A lunar eclipse begins when the Moon moves into Earth’s penumbra.
- As the Moon continues to move, it enters Earth’s umbra and you see a curved shadow on the Moon’s surface.

Section 2: The Moon – Earth’s Satellite
Eclipses of the Moon

• Upon moving completely into Earth’s umbra, the Moon goes dark, signaling that a **total** lunar eclipse has occurred.

• Sometimes sunlight bent through Earth’s atmosphere causes the eclipsed Moon to appear red.
Eclipses of the Moon

• A **partial** lunar eclipse occurs when only a portion of the Moon moves into Earth’s umbrella.

• The remainder of the Moon is in Earth’s penumbra and, therefore, receives some direct sunlight.

• A penumbral lunar eclipse occurs when the Moon is totally within Earth’s penumbra.
Eclipses of the Moon

• It is difficult to tell when a penumbral lunar eclipse occurs because some sunlight continues to fall on the side of the Moon facing Earth.

• A total lunar eclipse can be seen by anyone on the nighttime side of Earth where the Moon is not hidden by clouds.
Eclipses of the Moon

• In contrast, only a lucky few get to witness a total solar eclipse.

• Only those people in the small region where the Moon’s umbra strikes Earth can witness one.
The Moon’s Surface

• When you look at the Moon you can see many depressions called **craters**.

• Meteorites, asteroids, and comets striking the Moon’s surface created most of these craters, which formed early in the Moon’s history.

Section 2: The Moon – Earth’s Satellite
The Moon’s Surface

• Upon impact, cracks may have formed in the Moon’s crust, allowing lava to reach the surface and fill up the large craters.
The Moon’s Surface

• The resulting dark, flat regions are called maria.

• The igneous rocks of the maria are 3 to 4 billion years old.

• So far, they are the youngest rock to be found on the Moon.

• This indicates that craters formed after Moon’s surface originally cooled.
The Moon’s Surface

• The maria formed early enough in the Moon’s history that molten material still remained in the Moon’s interior.
• The Moon once must have been as geologically active as Earth is today.
• Before the Moon cooled to the current condition, the interior separated into distinct layers.
Inside the Moon

• Earthquakes allow scientists to learn about Earth’s interior.
• In a similar way, scientists use instruments to study moonquakes.
• The data they have received have led to the construction of several models of the Moon’s interior.
• One such model suggests that the Moon’s crust is about 60 km thick on the side facing Earth.

Section 2: The Moon – Earth’s Satellite
Inside the Moon

- On the far side, it is thought to be about 150 km thick.
- Under the crust, a solid mantle may extend to a depth of 1,000 km.
- A partly molten zone of mantle may extend even farther down.
- Below this mantle may lie a solid, iron-rich core.

Section 2: The Moon – Earth’s Satellite
The Moon’s Origin

• Before the *Apollo* space missions in the 1960s and 1970s, there were three leading theories about the Moon’s origin.

• According to one theory, the Moon was captured by Earth’s gravity.

Section 2: The Moon – Earth’s Satellite
The Moon’s Origin

• Another held that the Moon and Earth condensed from the same cloud of dust and gas.

• **Impact theory** of Moon origin says some 4.6 billion years ago Moon was thrown off when a large object collided with Earth.
The Moon in History

• Studying the Moon’s phases and eclipses led to the conclusion that both Earth and the Moon were in motion around the Sun.

• The curved shadow Earth casts on the Moon indicated to early scientist that Earth was spherical.
The Moon in History

• When Galileo first turned his telescope toward the Moon, he found a surface scarred by craters and maria.

• Before that time, many people believed that all planetary bodies were perfectly smooth and lacking surface features.

• Now, actual moon rocks are available for scientists to study.

Section 2: The Moon – Earth’s Satellite
A(n) ________ occurs when the Moon’s entire surface facing Earth reflects light.

A. eclipse
B. full moon
C. new moon
D. old moon
The answer is **B**.

During a full moon, the Moon’s entire surface facing Earth reflects light.
When do eclipses occur?
Eclipses occur when Earth or the Moon temporarily blocks the sunlight from reaching the other. They are described as solar or lunar eclipses, depending on which body is temporarily not visible.
In a solar eclipse, a person standing in the __________ experiences a total eclipse.

A. Earth’s penumbra
B. Earth’s umbra
C. Moon’s penumbra
D. Moon’s umbra
Section 2: The Moon – Earth’s Satellite

The answer is D.
This is the darkest portion of the Moon’s shadow.
Section 3: Exploring Earth’s Moon

Section Objectives

1. Describe recent discoveries about the Moon.

2. Examine facts about the Moon that might influence future space travel.
In 1959, the former Soviet Union launched the first Luna spacecraft, enabling up-close study of the Moon.

Two years later, the United States began a similar program with the first Ranger spacecraft and a series of Lunar Orbiters.

The spacecraft in these early missions took detailed photographs of the Moon.

Section 3: Exploring Earth’s Moon
Missions to the Moon

• The next step was the *Surveyor* spacecraft designed to take more detailed photographs and actually land on the Moon.
• Five of these spacecraft successfully landed on the lunar surface and performed the first analysis of lunar soil.
• The goal of the *Surveyor* program was to prepare for landing astronauts on the Moon.
Missions to the Moon

• This goal was achieved in 1969 by the astronauts of Apollo 11.

• By 1972, when Apollo missions ended, 12 U.S. astronauts had walked on the Moon.
Missions to the Moon

Section 3: Exploring Earth’s Moon

Moon Exploration

- **October 7, 1959**: Russian space probe Luna 3 returns first pictures of the Moon's far side.
- **July 31, 1964**: U.S. receives perfect photos from uncrewed probe Ranger 7 before it crash lands on the Moon.
- **June 2, 1966**: Surveyor 1, first of Seven U.S. Surveyor missions, makes a perfect soft landing on the Moon.
- **August 1966 - August 1967**: Five Lunar Orbiters launched by U.S. photograph virtually the entire Moon.
- **December 24, 1968**: Apollo 8, along with its crew, becomes the first mission to orbit the Moon.
- **July 20, 1969**: Apollo 11 lands on the moon. Neil Armstrong becomes the first human to set foot on another celestial body.
- **April 11, 1970**: Apollo 13 launched. Explosion causes mission to abort. Astronauts barely make it home.
- **December 11, 1972**: Apollo 17 lands on the Moon. The first geologist visits on the last crewed Moon mission.

**1959**  
**1964**  
**1965**  
**1966**  
**1967**  
**1968**  
**1969**  
**1970**  
**1971**  
**1972**  
**1973**
Surveying the Moon

- In 1994, the *Clementine* was placed into lunar orbit to conduct a two-month *survey* of Moon’s surface.
- An important aspect of this study was collecting data on the *mineral* content of Moon rocks.
- While in orbit, *Clementine* also mapped features on the Moon’s surface, including huge impact basins.
Impact Basins

• When meteorites and other objects strike the Moon, they leave behind depressions in the Moon’s surface.

• The depression left behind by an object striking the Moon is known as an **impact basin**, or impact crater.

• The **South Pole-Aitken Basin** is the oldest identifiable impact feature on the Moon’s surface.
Temperatures in shadowed areas would be extremely low, probably never more than \(-173^\circ C\).

Impact Basins

- Impact basins at the poles were of special interest to scientists.
- The Sun’s rays never strike directly, so the crater bottoms are always in a shadow.
- Temperatures in shadowed areas would be extremely low, probably never more than \(-173^\circ C\).
Impact Basins

• Scientists hypothesize that any ice deposited by comets impacting the Moon throughout its history would remain in these shadowed areas.
• Early signals from Clementine indicated the presence of water.
• This was intriguing, because it could be a source of water for future moon colonies.
Mapping the Moon

• A large part of *Clementine’s* mission included taking high-resolution photographs so a detailed map of the Moon’s surface could be compiled.
Mapping the Moon

- Based on analysis of the light data received from Clementine, a global map of the Moon also was created that shows its composition.
- Information shows that the Moon’s crust is thinnest under impact basins.
Mapping the Moon

• One image resulting from *Clementine* data shows that the crust on the side of the Moon that faces Earth is much *thinner* than the crust on the far side.
The Lunar Prospector

• In 1998, NASA launched the desk-sized *Lunar Prospector* into lunar orbit to look for clues about the Moon’s origin and makeup.

• The spacecraft spent a year orbiting the Moon from pole to pole, once every two hours.

• The resulting maps confirmed the *Clementine* data.

Section 3: Exploring Earth’s Moon
The Lunar Prospector

- Also, data from *Lunar Prospector* confirmed that the Moon has a small, iron-rich core about 600 km in diameter.

- A small core supports the impact theory of how the Moon formed—only a small amount of iron could be blasted away from Earth.
Icy Poles

- *Lunar Prospector* carried instrument designed to map the Moon’s gravity, magnetic field, and the abundance of 11 elements in the lunar crust.
- This provided scientists with data from the entire lunar surface rather than just the areas around the Moon’s equator, which had been gathered earlier.

Section 3: Exploring Earth’s Moon
Icy Poles

- Also, *Lunar Prospector* confirmed the findings of *Clementine* that water ice was present in deep craters at both lunar poles.
The space mission that accomplished the landing of U.S. astronauts on the Moon was __________.

A. Apollo
B. Lunar Orbiter
C. Surveyor
D. Voyager
The answer is A. The astronauts of Apollo 11 landed on the Moon.
Section 3 Question 2

What is an impact basin?

Answer

An impact basin, or impact crater, is a depression left behind by an object striking the Moon.
An impact basin, or impact crater, is a depression left behind by an object striking the Moon.
Section 3 Question 3

The mission of the spacecraft *Clementine* was to map the surface of __________.

A. Earth  
B. Mars  
C. the Moon  
D. Venus
Clementine took high-resolution photographs enabling the compilation of a detailed map of the Moon’s surface.