

Objectives

- **Identify** the relative positions and motions of Earth, the Sun, and the Moon.
- **Describe** the phases of the Moon.
- **Explain** eclipses of the Sun and Moon.

Vocabulary

- ecliptic
- summer solstice
- winter solstice
- autumnal equinox
- vernal equinox
- synchronous rotation
- solar eclipse
- perigee
- apogee
- lunar eclipse



The Sun-Earth-Moon System

- The relationships between the Sun, Moon, and Earth are important to us in many ways.
 - The Sun provides light and warmth, and it is the source of most of the energy that fuels our society.
 - The Moon raises tides in our oceans and illuminates our sky with its monthly cycle of phases.
 - Every society from ancient times to the present has based its calendar and its timekeeping system on the apparent motions of the Sun and Moon.



Daily Motions

- The Sun rises in the east and sets in the west, as do the Moon, planets, and stars as a result of Earth's rotation.
- We observe the sky from a planet that rotates once every day, or 15° per hour.



Daily Motions

Earth's Rotation

- There are two relatively simple ways to demonstrate that Earth is rotating.
 1. A Foucault pendulum, which has a long wire, a heavy weight, and will swing in a constant direction, appears from our point of view to shift its orientation.
 2. Flowing air and water on Earth are diverted from a north-south direction to an east-west direction as a result of Earth's rotation in what is known as the Coriolis effect.



Daily Motions

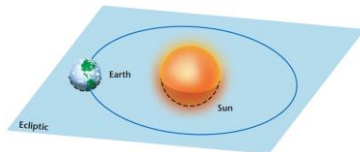
Earth's Rotation

- The length of a day as we observe it is a little longer than the time it takes Earth to rotate once on its axis.
- Our timekeeping system is based on the solar day, which is the time period from one sunrise or sunset to the next.



Annual Motions

- The annual changes in length of days and temperature are the result of Earth's orbital motion about the Sun.
- The **ecliptic** is the plane in which Earth orbits about the Sun.



Annual Motions

The Effects of Earth's Tilt

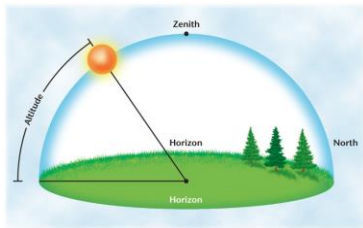
- Earth's axis is tilted relative to the ecliptic at approximately 23.5° .
- As Earth orbits the Sun, the orientation of Earth's axis remains fixed in space.
- At one point, the northern hemisphere of Earth is tilted toward the Sun, while six months later it is tipped away from the Sun.
- As a result of the tilt of Earth's axis and Earth's motion around the Sun, the Sun is at a higher altitude in the sky during summer than in the winter.



Annual Motions

The Effects of Earth's Tilt

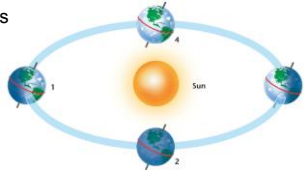
Altitude is measured in degrees from the observer's horizon to the object. There are 90 degrees from the horizon to the point directly overhead, called the zenith of the observer.



Annual Motions

Solstices

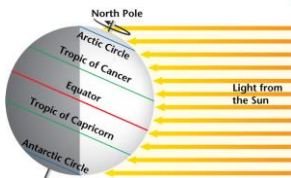
- As Earth moves from position 1, through position 2, to position 3, the altitude of the Sun decreases in the northern hemisphere.
- Once Earth is at position 3, the Sun's altitude starts to increase as Earth moves through position 4 and back to position 1.



Annual Motions

Solstices

- The **summer solstice** occurs around June 21 each year when the Sun is directly overhead at the Tropic of Cancer, which is at 23.5° N.
- The summer solstice corresponds to the Sun's maximum altitude in the sky in the northern hemisphere.

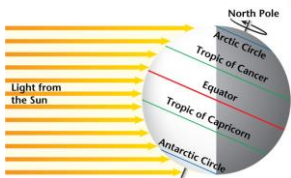


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Annual Motions

Solstices

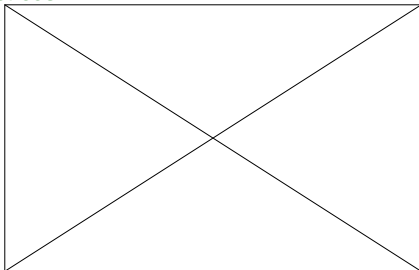
- The **winter solstice** occurs around December 21 each year when the Sun is directly overhead at the Tropic of Capricorn which is at 23.5° S.
- The winter solstice corresponds to the Sun's lowest altitude in the sky in the northern hemisphere.



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Annual Motions

Solstices



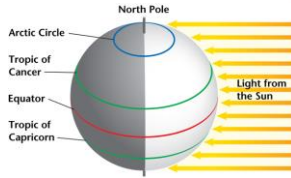
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Annual Motions

Equinoxes

– When the Sun is directly overhead at the equator, both hemispheres receive equal amounts of sunlight.

- The **autumnal equinox** occurs around September 21, halfway between the summer and the winter solstices when the Sun is directly over the equator.

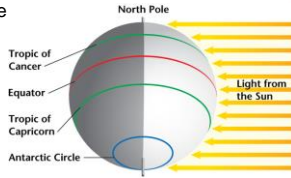


Annual Motions

Equinoxes

– The **vernal equinox** occurs around March 21, halfway between the winter and the summer solstices when the Sun is directly over the equator.

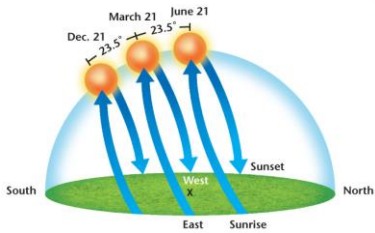
- For an observer at the Tropic of Cancer or Tropic of Capricorn, the Sun is 23.5° from the point directly overhead during the equinoxes.



Annual Motions

Equinoxes

For a person standing at the x at 23.5° N, the Sun would appear in these positions on the winter solstice, the vernal equinox, and the summer solstice. On the autumnal equinox, the Sun would be at the same altitude as on the vernal equinox.

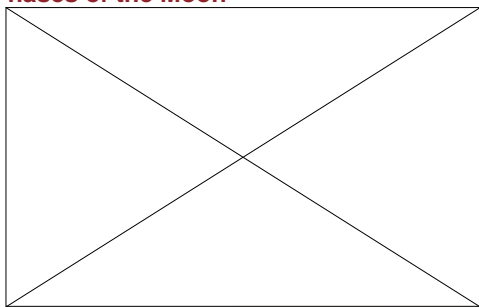


Phases of the Moon

- The sequential changes in the appearance of the Moon are called lunar phases.
 - A new moon occurs when the Moon is between Earth and the Sun and we cannot see the Moon because the sunlit side is facing away from us.
 - As the Moon moves along in its orbit, the amount of reflected sunlight that we can see increases until we are able to see the entire sunlit side of the Moon, known as a full moon.
 - Once a full moon is reached, the portion of the sunlit side that we see begins to decrease as the Moon moves back toward the new-moon position.



Phases of the Moon



Phases of the Moon

Synchronous Rotation

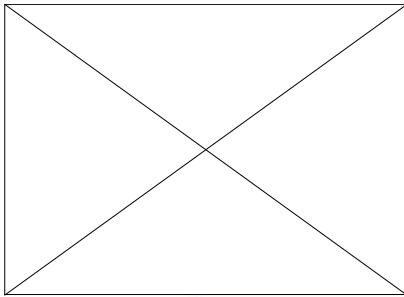
- **Synchronous rotation** is the state at which orbital and rotational periods are equal.
 - As the Moon orbits Earth, the same side faces Earth at all times because the Moon has a synchronous rotation, spinning exactly once each time it goes around Earth.



Motions of the Moon

- The length of time it takes for the Moon to go through a complete cycle of phases is called a lunar month.
- The length of a lunar month is about 29.5 days, which is longer than the 27.3 days it takes for one revolution, or orbit, around Earth.
- The Moon also rises and sets 50 minutes later each day because the Moon has moved 13° in its orbit over a 24-hour period, and Earth has to turn an additional 13° for the Moon to rise.

Motions of the Moon



Motions of the Moon

Tides

- The Moon's gravity pulls on Earth along an imaginary line connecting Earth and the Moon, creating bulges of ocean water on both the near and far sides of Earth.
- As Earth rotates, these bulges remain aligned with the Moon.
- When the Sun and Moon are aligned along the same direction, the result is higher-than-normal tides, called spring tides.
- When the Moon is at a right angle to the Sun-Earth line, the result is lower-than-normal tides, called neap tides.

Solar Eclipses

- A **solar eclipse** occurs when the Moon passes directly between the Sun and Earth and blocks our view of the Sun.
 - When the Moon perfectly blocks the Sun's disk, we see only the dim, outer gaseous layers of the Sun in what is called a total solar eclipse.
 - A partial solar eclipse is seen when the Moon blocks only a portion of the Sun's disk.

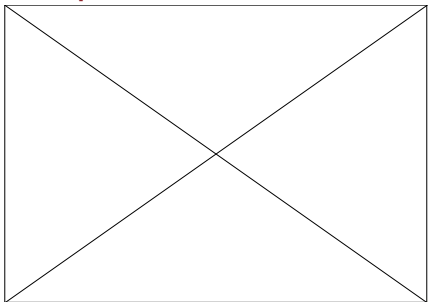


Solar Eclipses

- The shadow that is cast on Earth consists of two regions.
 - A total eclipse occurs in the inner portion called the umbra, which does not receive direct sunlight.
 - A partial eclipse occurs in the outer portion of the shadow called the penumbra, where some of the Sun's light reaches.



Solar Eclipses



Solar Eclipses

The Effects of Orbits

- The Moon's orbit is tilted 5° relative to the ecliptic and usually the Moon passes north or south of the Sun as seen from Earth, during a new moon.
- A solar eclipse can occur only when the intersection of the Moon and the ecliptic is in a line with the Sun and Earth.



Solar Eclipses

The Effects of Orbits

- The Moon's distance from Earth increases and decreases as the Moon moves in its elliptical orbit around Earth.
- **Perigee** is the closest point in the Moon's orbit to Earth.
- **Apogee** is the farthest point in the Moon's orbit from Earth.
- When the Moon is near apogee, it appears smaller, and thus it does not completely block the disk of the Sun, resulting in an annular eclipse.

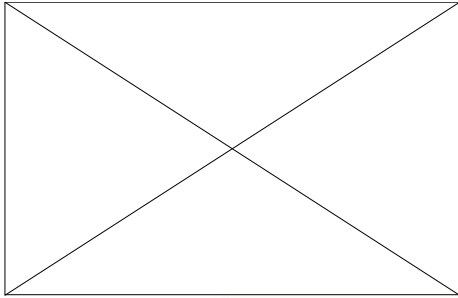


Lunar Eclipses

- A **lunar eclipse** occurs when the full Moon passes through Earth's shadow.
- A lunar eclipse can happen only at the time of a full moon, when the Moon is in the opposite direction from the Sun.
- A total lunar eclipse occurs when the entire Moon is within Earth's umbra.
- Solar and lunar eclipses occur in almost equal numbers, with slightly more lunar eclipses.



Lunar Eclipses



Section Assessment

1. Match the following terms with their definitions.

- | | |
|--------------------------|---|
| <u>C</u> ecliptic | A. occurs when the Sun is directly overhead at the Tropic of Cancer |
| <u>A</u> summer solstice | B. the point in the Moon's elliptical orbit that is the farthest from Earth |
| <u>D</u> winter solstice | C. the plane that contains Earth's orbit |
| <u>B</u> apogee | D. occurs when the Sun is directly overhead at the Tropic of Capricorn |



Section Assessment

2. Number the lunar phases in the correct order, beginning after the new moon.

- 3 waxing gibbous
- 4 full moon
- 7 waning crescent
- 6 third quarter
- 2 first quarter
- 5 waning gibbous
- 1 waxing crescent



Section Assessment

3. Identify whether the following statements are true or false.

false A maximum of five eclipses, solar and lunar combined, can occur in a year.

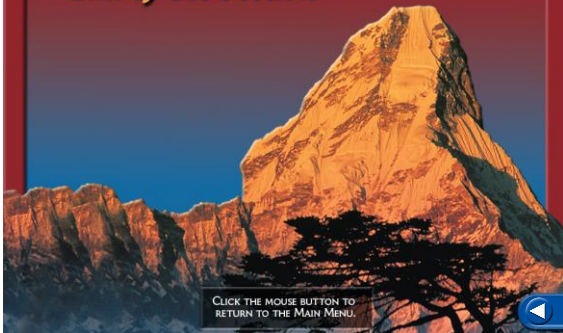
true The Sun will appear at the same altitude in the sky during both the autumnal and vernal equinoxes.

false The Earth has a synchronous rotation.

true To witness a total solar eclipse, you must be inside the umbra of the Moon's shadow.



End of the Section



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