Chapter 1
Cycles of the Sky

The Celestial Sphere

- Vast distances to stars prevent us from sensing their true 3-D arrangement
- Naked eye observations treat all stars at the same distance, on a giant celestial sphere with the Earth at its center

Models and Science

- The celestial sphere is a model, which does not necessarily match physical reality
- Models provide a means to enhance our understanding of nature

Constellations

- Constellations are fixed arrangements of stars that resemble animals, objects, and mythological figures
- Stars in a constellation are not physically related

Constellations

- Positions of stars change very slowly; constellations will look the same for thousands of years
- Origin of the ancient constellations is unknown although they probably served as mnemonic tools for tracking seasons and navigation

Diurnal vs. Annular Motion

- Diurnal Motion
  - “Daily Motion”
  - Sun, Moon, planets, and stars rise in the east and set in the west
  - Due to the Earth’s rotation

- Annual Motion
  - “Yearly Motion”
  - Due to the Earth’s revolution
  - Is the sky different from day to day?
  - Month to month?
  - Year to year?

- Ancient astronomers took all celestial motion to be diurnal
- The Celestial Sphere?
Diurnal Motion

- Daily motion can be explained by the rotation of the celestial sphere about the north and south celestial poles located directly above the Earth’s north and south poles.
- The celestial equator, which lies directly above the Earth’s equator, provides another astronomical reference marker.

Annual Motion

- For a given time (say 10:00 PM), as the months proceed, constellations do not appear in the same part of the sky.

Annual Motion

- A given star rises 3 minutes 56 seconds earlier each night.
- This annual motion is caused by the Earth’s motion around the Sun, the result of projection.
- The ancients used the periodic annual motion to mark the seasons.

The Ecliptic

- The path of the Sun through the stars on the celestial sphere is called the ecliptic.
- The ecliptic is a projection of the Earth’s orbit onto the celestial sphere and is tipped relative to the celestial equator.

The Seasons

- The Earth is closest to the Sun in January, which is winter in the northern hemisphere.
- Therefore, the seasons cannot be caused by the Sun’s proximity to the Earth.
- The Earth’s rotation axis is tilted 23.5° from a line perpendicular to the Earth’s orbital plane.

The Seasons

- The rotation axis of the Earth maintains nearly the same tilt and direction from year to year.
- The northern and southern hemispheres alternate receiving (on a yearly cycle) the majority of direct light from the Sun.
- This leads to the seasons!
The Seasons

- The tilt of the Earth’s rotation axis causes the ecliptic not to be aligned with the celestial equator.
- Sun is above the celestial equator in June when the Northern Hemisphere is tipped toward the Sun, and is below the equator in December when tipped away.
- Tilting explains seasonal altitude of Sun at noon, highest in summer and lowest in winter.

The Ecliptic’s Tilt

- Points on the horizon where the Sun rises and sets change periodically throughout the year.
- In summer months of the Northern hemisphere, the Sun rises north of east and sets north of west.
- In winter months of the Northern hemisphere, the Sun rises south of east and sets south of west.
- The solstices (about June 21 and December 21) are when the Sun rises at the most extreme north and south points.
- The equinoxes (about March 21 and September 23) are when the Sun rises directly east.
- Ancients marked the position of the Sun rising and setting to determine the seasons (e.g., Stonehenge).

Solstices and Equinoxes

- Rises in the east and sets in the west.
- Like the planets and Sun, the Moon moves from west to east relative to the stars (roughly the width of the Moon in one hour).

The Moon
The Phases of the Moon

- During a period of about 30 days, the Moon goes through a complete set of phases: new, waxing crescent, first quarter, waxing gibbous, full, waning gibbous, third quarter, waning crescent.

Lunar Rise and Set Times

- The Moon rises roughly 50 minutes later each day.

Eclipses

- An eclipse occurs when the Sun, Earth, and Moon are directly in line with each other.
- A solar eclipse occurs when the Moon passes between the Sun and Earth, with the Moon casting its shadow on the Earth causing a midday sky to become dark as night for a few minutes.

Lunar Eclipses

- A lunar eclipse occurs when the Earth passes between the Sun and Moon, with the Earth casting its shadow on the Moon giving it a dull red color.
Rarity of Eclipses

- Because of the Moon’s tilt relative to the ecliptic, eclipses will not occur at every new and full Moon.
- Twice a year the Moon’s orbit will pass through the Sun giving the possibility of an eclipse – these times are called eclipse seasons.

Eclipse Seasons

- Since the Moon’s orbit tilts nearly in the same direction through the year, twice a year the Moon’s orbit will pass through the Sun giving the possibility of an eclipse – these times are called eclipse seasons.
- When a solar eclipse occurs at new Moon, conditions are right for a lunar eclipse to occur at the full Moon either before or after the solar eclipse.

Eclipse Periods

- Eclipses do not occur every 30 days since the Moon’s orbit is tipped relative to the Earth’s orbit.
- The tipped orbit allows the shadow of the Earth (Moon) to miss the Moon (Earth).

Recent and Upcoming Solar Eclipses