Chapter 1
The Copernican Revolution: The Birth of Modern Science

* Ancient Astronomy
  * Early Greeks (600 B.C. - A.D. 150)
    - 7 wandering objects known
    - Earth sat motionless at the center of the solar system
    - Idea 1st employed by Aristotle
    - Couldn't account for retrograde motion or varying brightness of planets
  * Aristotle (384 B.C. - 322 B.C.)
    - Believed in the geocentric view
    - Model based on perfect circular formation
    - Thought Earth was spherical
  * Eratosthenes (276 B.C. - 194 B.C.)
    - Found 2 cities north and south of each (Alexandria and Syene)
    - Realized that on June 21st at noon, the two cities had different angled shadows created by the Sun
    - Shadow angles differed by 7 degrees
    - 7 degrees / 360 degrees reduces to 1/50
    - Multiplying the distance between the two cities by 50 yields Earth’s circumference
  * Aristarchus (310 B.C. - 230 B.C.)
    - 1st to propose the Sun-centered (heliocentric) universe
    - Explained Earth rotated each day
    - Idea was not widely accepted
  * Claudius Ptolemy (83 A.D. – 168 A.D.)
    - Believed in the Earth centered universe
    - Planets/Sun revolve around Earth in circular orbits
    - Ptolemaic model worked, but the reasoning was incorrect
      - Flaws existed because of the Earth centered universe idea and perfect circular orbits
  * Sun centered system
  * Ptolemaic model survived for 13 centuries
    - Rediscovered Aristarchus' heliocentric model
    - Earth spins on its axis and orbits the Sun
      - Explains daily and seasonal changes
      - Explains retrograde motion and varying planetary brightness
      - - realization that Earth is not central
    - Believed in perfect circular orbits
    - Used epicycles and deferents to explain observations
Published on his deathbed, so received no criticism

The birth of modern astronomy

- Ideas began with Copernicus and continued with Galileo
- Believed in the heliocentric system
  - Found mountains, craters, valleys on Moon
  - Found 4 Moons surrounding Jupiter
  - Planets shown as circular disks, not specks of light

- Found sunspots (led to his blindness)
- Sentenced to permanent house arrest for acknowledging the Sun centered system

Tycho Brahe (1546-1601)
- Made extensive observations of planets
- Didn't believe in Copernican system since planetary observations didn’t match the system

- 1st law – planets have elliptical orbits
  - Eccentricity – elliptical value of a planet's orbit
- 2nd law - planets have variations in orbital speeds
- 3rd law – the period of planet is related to its distance from the Sun
  - \( P = \text{period (years)} \)
  - \( D = \text{distance in astronomical units (AU)} \)

  - 1 AU is approximately 93 million miles

Isaac Newton (1643 - 1727)
- Developed the 3 laws of motion
  - 1st law - object at rest tends to stay at rest, object in motion tends to stay in motion
    - Acceleration - rate of change of velocity
  - 2nd law - acceleration is directly proportional to the force and inversely proportional to the mass
    - Greater force or less mass, the greater the acceleration
  - 3rd law - forces on objects are equal but opposite in magnitude

- Law of universal gravitation - every body in the universe attracts every body with a force that is directly proportional to their masses and inversely proportional to the square of the distance between them. The greater the mass of the object, the greater its gravitational force
  - A person’s mass is the same on the Earth and the Moon, but a person weighs about ________________ on the Moon than on the Earth
* Kepler's laws reconsidered
  • Newton updated Kepler's laws
  • Kepler's 1st law should say the orbits of the planets are ellipses around a common center of mass
  • \( \frac{P^2}{d^3} / \frac{m_{\text{total}}}{M} \) (in solar mass)
    – Solar mass (M)
    – Common center of mass of the solar system is found within the Sun

Earth’s Orbital Motion
* Day to day changes
  * _____________ - turning of the Earth on its axis
    • Causes day and night
    • One rotation is approximately 24 hours
      – ______________ – the time it takes to go from noon to noon (24 hours)
      – _______________ - the time for one full rotation (360°) ~ 23 hours, 56 minutes, and 4 seconds

* Seasonal changes
  * Earth orbits the Sun at an average speed of 70,000 mph
  * ______________ - orbit of Earth around the Sun
    • Tropical year (365.242 days) - time from one vernal equinox to the next
      – Calendars use this
    • Sidereal year - one complete revolution (365.256 days)
    • We must make up the difference with leap year
    • If there was no leap year, summer would be in mid-February in 13,000 years
    • Orion would also become a summer constellation
  * Ecliptic - apparent annual path of the Sun against the background stars
  * Earth's axis of rotation (__________________________) is tilted 23.44 degrees
    • Causes our seasons
  * Vernal equinox - March 20-21 (12 hours of daylight everywhere)
  * Autumnal equinox - September 22-23 (12 hours of daylight everywhere)
  * _____________ - 12 constellations through which the Sun passes over a year

* Long term changes
  * Precession -
    • Axis points toward north star (Polaris), 13,000 years it will be Vega, then 26,000 years Polaris again.
    • Caused by gravitational pull of Moon and Sun
  * Earth’s tilt axis varies between 22.1° and 24.5° over a 42,000 year period
    – Currently the tilt is decreasing
    – Caused by the tidal forces of the Sun and Moon
  * Eccentricity variance – the changing shape of Earth’s orbit
    • Varies from nearly circular to elliptical over a period of 100,000 years
  * Milankovitch cycle – changes on Earth’s climate from Earth’s changing motions
  * __________________ – the apparent backwards motion of the planets against the background stars
* Perihelion –
  • Currently around January 3\textsuperscript{rd}
* ___________________ – Earth’s farthest from the Sun (94.5 million miles)
  • Currently around July 4\textsuperscript{th}

Motions of the Moon
* Phases of the Moon
  * Approximately 30 days to complete cycle
  * New Moon, waxing crescent, 1\textsuperscript{st} quarter, waxing gibbous, full Moon, waning gibbous, last (3\textsuperscript{rd}) quarter, waning crescent
  * Earthshine – light reflected off the Earth partially illuminates the darkened Moon
* Lunar motions
  * ___________________ – 29\frac{1}{2} days for the Moon to complete its phases
  * Sidereal month - ____________ for the Moon to complete one orbit around the Earth
* Temperatures
  * Day side of Moon = ____________
  * Night side of Moon = ____________

Eclipses
* Lunar -
  • Can last up to 100 minutes
  • Moon appears red due to refracted light from Earth’s atmosphere
  • Viewable from all locations at night
  • Lunar eclipse schedule
  • Time lapse animation
* Solar - Moon moves between Sun and Earth
  * Planets stars become viewable when total
  * Only viewable from small portion of Earth
  * Penumbra - partial shadow
  * ___________________ (Time lapse animation)
  * Can never last more than 7.5 minutes
  * Needs perfect alignment
  * Schedule map and web link
* ___________________ – when the shadow doesn't fully cover disk
  * More common
  * Imperfect alignments
* Annular eclipse -
  *
  * Half of all solar eclipses are annular

*End of Chapter 1*