Lecture #5: Plan

• The Beginnings of Modern Astronomy
• Kepler’s Laws
• Galileo
• Newton’s Laws
The Beginnings of Modern Astronomy

- Tycho Brahe (Denmark, 1546 – 1601)
  - Made detailed observations of planetary positions (to within ~1/60th degree = 1 arc min)
The Beginnings of Modern Astronomy

• Johannes Kepler (Denmark, 1571 – 1630)
  — Used data of Tycho (his mentor) to derive the laws of planetary motion
  → “Kepler’s Laws”
Kepler’s First Law

1. Planets move in elliptical orbits with the Sun at one focus of the ellipse
2. Planets sweeps out equal areas in equal times = “Equal Area Law”
Kepler’s Third Law

3. Orbital period is related to orbital size:

\[ P^2 = a^3 \]

- \( P \) is the period (in years)
- \( a \) is the semi-major axis (in A.U.)
Kepler’s Third Law

Example:

Jupiter is 5.2 A.U. from the Sun. What is its Period?

\[ P^2 = a^3 \]
\[ P^2 = (5.2)^3 = 5.2 \times 5.2 \times 5.2 \]
\[ = 140.6 \]

\[ P = \sqrt{140.6} \approx \sqrt{12 \times 12} \]
\[ \approx 12 \text{ years} \text{ (11.9 years)} \]
Galileo Galilei (Italy, 1564-1642)

- Applied telescope to study the Heavens
  - Earth is not at the center of all motions
- Discovered moons (satellites) orbiting Jupiter
  - Venus orbits Sun, not the Earth
- Discovered phases of Venus
  - Venus orbits Sun, not the Earth
- Observed craters on the Moon and sunspots on the Sun
  - Moon & Sun are “imperfect” like Earth
- One of the principal founders of the experimental method for studying scientific problems.
Galileo Galilei (Italy, 1564-1642)

• **Inertia:**

  Tendency of an object at rest to remain at rest & an object in motion to keep moving

  \[
  \text{mass} = \text{measure of an object’s inertia}
  \]
Isaac Newton (England, 1642-1727)

- Isaac Newton described the fundamental laws covering the motion of bodies ("Laws of Motion" or "Newton’s Laws")
- Had to invent his own mathematics (Calculus) to do it!
- And he did most of it before his 24th birthday…
First Law of Motion

• An object at rest remains at rest; an object in motion continues to move in a straight line unless a net force acts on it.

• Such motion is called **uniform motion**

• Motion involving change of speed and / or direction is **non-uniform motion**

→ Acceleration
Acceleration

- Change in a body’s velocity over time
- Change in an object’s direction of motion
First Law of Motion

• **Consequences:** Orbital motion follows a *curved path*
  → A net force must be acting on them
  → Gravity!
First Law of Motion

If string is released when ball is here, ball goes straight toward A, not toward B, nor toward C.
Second Law of Motion

\[ F = m \ a \]

\( F \) : force
\( m \) : mass
\( a \) : acceleration

Relates acceleration of an object to the force acting on it
Second Law of Motion

\[ a = \frac{F}{m} \]
Third Law of Motion

• When two bodies interact, they create *equal and opposite* forces on each other

• **Note:** the forces are equal but must obey $F = m \ a$
  → Acceleration are *not* equal
  → Principle behind how rockets work!
Third Law of Motion

\[ a = \frac{F}{m} \]