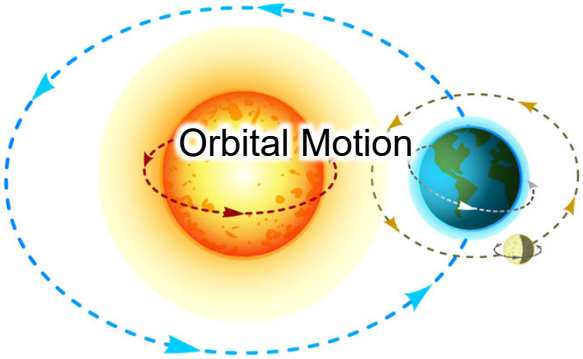


- The orbital motion of all celestial bodies in the universe are governed by gravitational force.
- Many orbits can be approximated as a class of orbit having the following characteristics:
  - A small mass m orbits a much larger mass M.
  - The system is isolated from other masses.

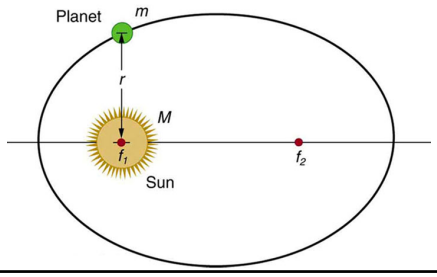
Kepler's Laws of Planetary Motion

- Tycho Brahe (Danish)
  - Made accurate and comprehensive astronomical observations.

- Johannes Kepler (German)
  - Worked with Brahe and devised laws that describe the motion of planets after careful study (over some 20 years) of Brahe's data.

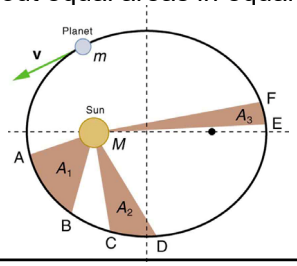
Kepler's First Law

- The orbit of each planet about the Sun is an ellipse with the Sun at one focus.



Kepler's Second Law

- Each planet moves so that an imaginary line drawn from the Sun to the planet sweeps out equal areas in equal times.

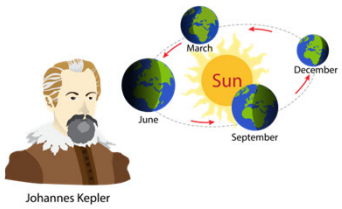


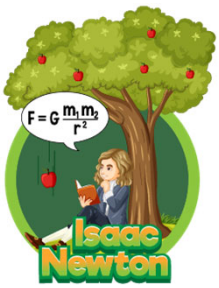
Kepler's Third Law

- The ratio of the squares of the periods of any two planets about the Sun is equal to the ratio of the cubes of their average distances from the Sun.

$$\frac{T_1^2}{T_2^2} = \frac{r_1^3}{r_2^3}$$

- Newton's Law of Universal Gravitation provided a theoretical basis for Kepler's Third Law of planetary motion.





Deriving Kepler's Third Law

- Consider a small mass m in a circular orbit about a large mass M.

$$F_{net} = \frac{mv^2}{r} \qquad v = \frac{2\pi r}{T}$$

$$F_{net} = \frac{m4\pi^2 r}{T^2}$$

- The net external force is caused by gravity.

$$G\frac{Mm}{r^2} = \frac{m4\pi^2 r}{T^2}$$

- Solving for T^2 gives

$$T^2 = \frac{4\pi^2}{GM}r^3$$

- Dividing by r^3 gives

$$\frac{T^2}{r^3} = \frac{4\pi^2}{GM}$$

- Comparing two planets gives

$$\frac{T_1^2}{r_1^3} = \frac{4\pi^2}{GM} \quad \text{and} \quad \frac{T_2^2}{r_2^3} = \frac{4\pi^2}{GM}$$

$$\frac{T_1^2}{r_1^3} = \frac{T_2^2}{r_2^3}$$

$$\frac{T_1^2}{T_2^2} = \frac{r_1^3}{r_2^3}$$

(Kepler's Third Law)