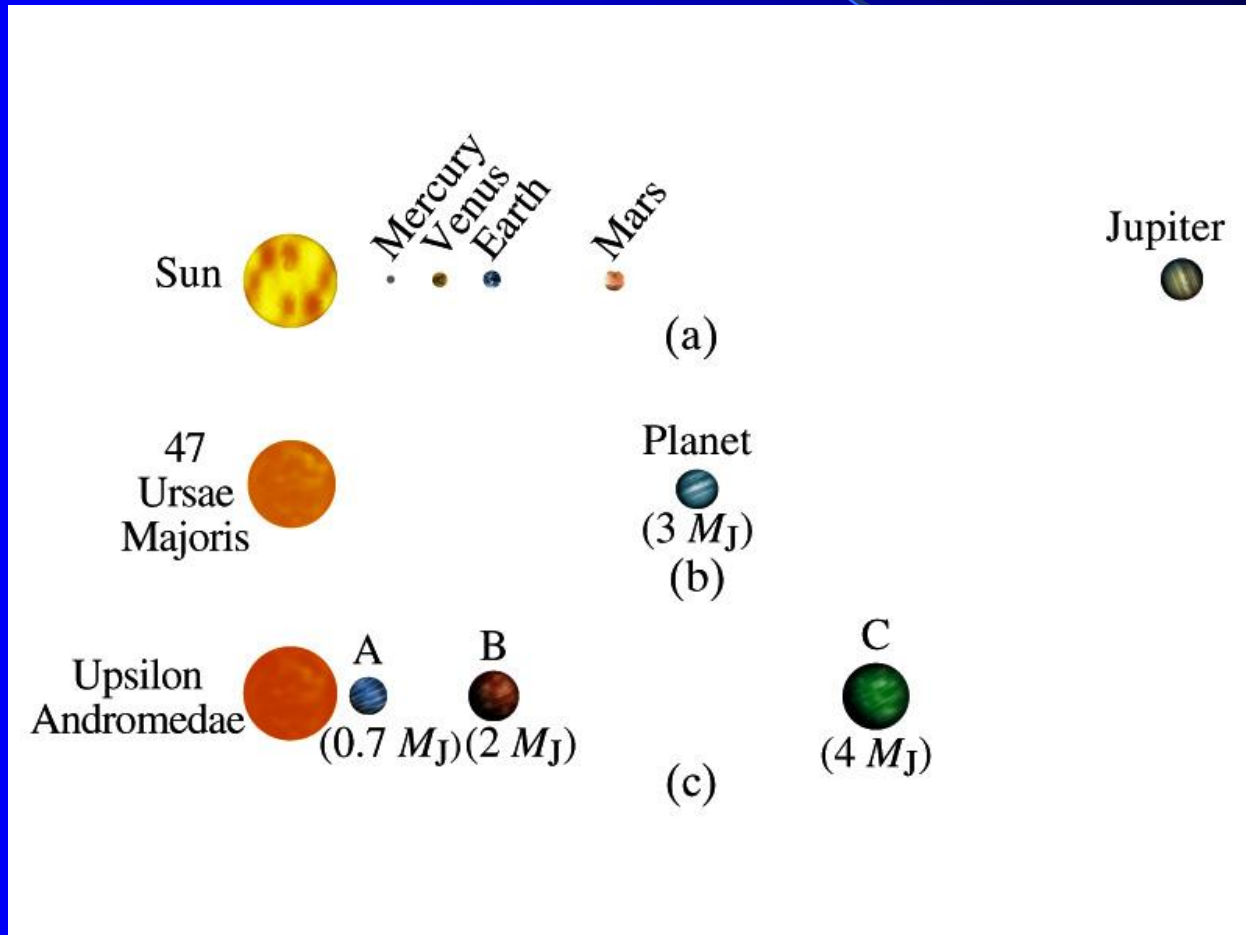
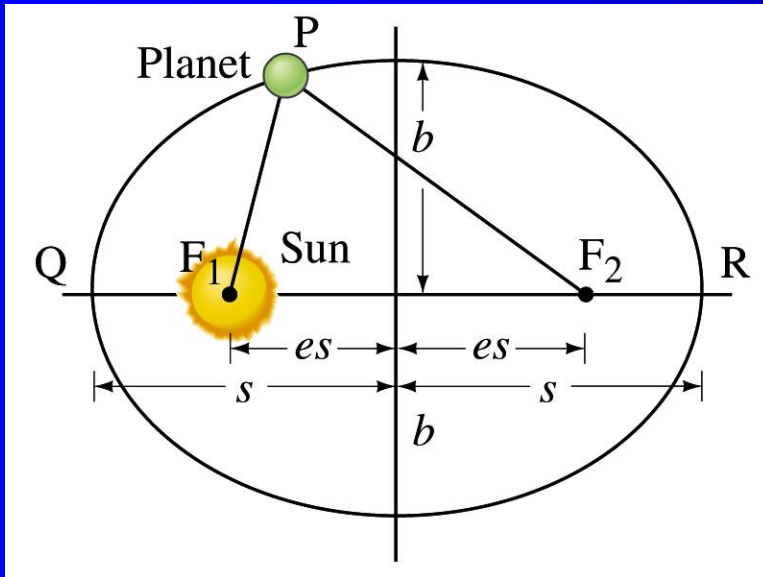


Planets

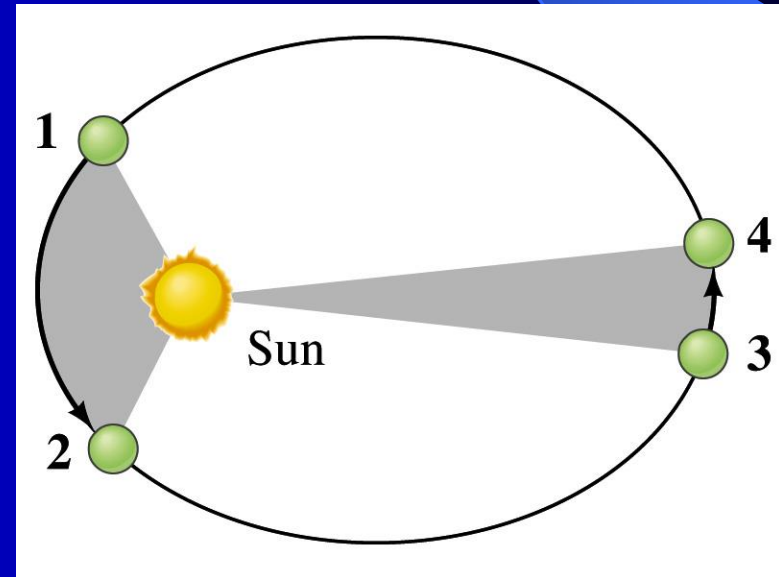


Kepler's Laws (1. and 2.)

1. Planet path about Sun is an ellipse with the sun at the focus point



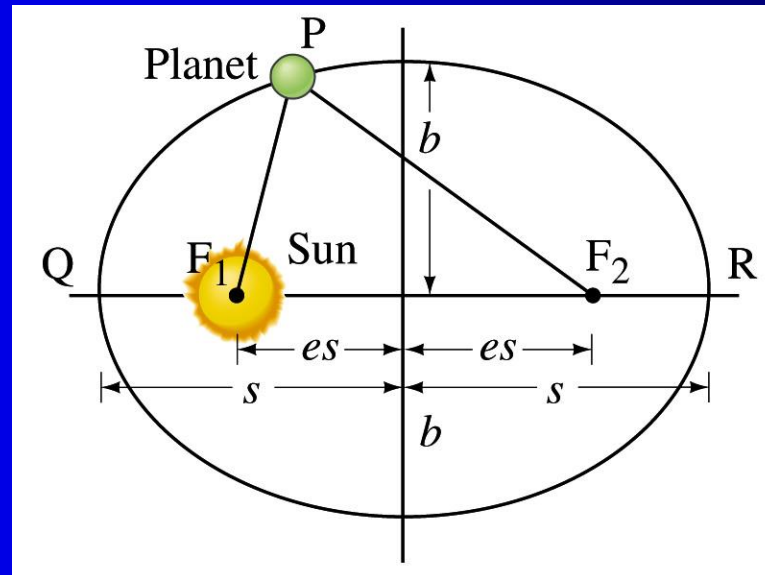
2. Line Sun-Planet sweeps equal areas in equal periods



Kepler's Laws (3.)

3. Ratio of Squares of the periods of two planets revolving around the sun is equal to the ratio of the cubes of their semimajor axes.

$$(T_1/T_2)^2 = (s_1/s_2)^3$$



Kepler's Laws (3.)

Derivation of $(T_1/T_2)^2 = (r_1/r_2)^3$ for a circular orbit

Planet 1: $r_1, m_1: F_G = F_{\text{centri}}$
 $\Rightarrow G (m_1 M_S) / r_1^2 = m_1 v_1^2 / r_1$
substitute $v_1 = 2\pi r_1 / T_1$

$$G (m_1 M_S) / r_1^2 = m_1 4\pi^2 r_1 / T_1^2$$

$$\text{Rearrange: } T_1^2 / r_1^3 = 4\pi^2 / GM_S$$

Planet 2: $r_2, m_2: F_G = F_{\text{centri}}$
 $\Rightarrow G (m_2 M_S) / r_2^2 = m_2 v_2^2 / r_2$
substitute $v_2 = 2\pi r_2 / T_2$

$$G (m_2 M_S) / r_2^2 = m_2 4\pi^2 r_2 / T_2^2$$

$$\text{Rearrange: } T_2^2 / r_2^3 = 4\pi^2 / GM_S$$

$$T_1^2 / r_1^3 = 4\pi^2 / GM_S = T_2^2 / r_2^3 \Rightarrow (T_1/T_2)^2 = (r_1/r_2)^3$$

Causality / Gravitational Field

- Cause and Effect
- Contact Force
- Force acting at a distance
- Field

$$\mathbf{g} = \mathbf{F}/m = 1/m G (m M) / r^2 \check{\mathbf{r}} = G M / r^2 \check{\mathbf{r}}$$

Principle of Equivalent Masses

- Inertial mass: $F = ma$
- Gravitational mass: $F = G (m M) / r^2$
- These don't have to be the same masses!
- But to 1 part in 10^{12} accuracy, they are!