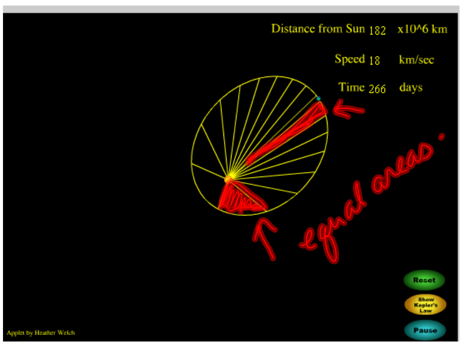
Chapter 12 - Universal Gravitation

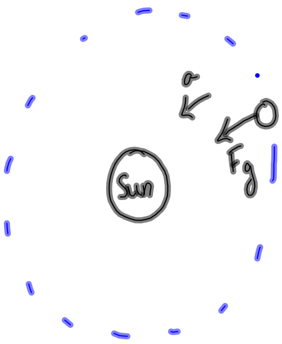
§12-1 Newton's Law of Universal Gravitation

Kepler laid the groundwork for Newton:

Kepler's Laws

1. Planets have elliptical orbits (orbit the Sun)
2. Planets sweep equal areas in equal times.





3. Every planet has a constant ratio

$$\frac{r_1^3}{T_1^2} = \frac{r_2^3}{T_2^2} \leftarrow \text{of } \frac{r^3}{T^2} = K \leftarrow \text{Kepler's constant}$$

$$K_{sun} = 3.35 \times 10^{18}\ m^3/s^2$$

↑ Sun is the centre of the orbit

Kepler's constant is unique for every "central" body.

$$K_{earth} \neq K_{sun} \neq K_{jupiter}$$

Newton's Law of Universal Gravitation

Recall: $F_g = mg$ where $g = 9.81 m/s^2$ (near earth's surface)
the value of g depends on location.

Newton said:

$F_g \propto m_1$
$F_g \propto m_2$
$F_g \propto \frac{1}{r^2}$

$F_g \propto \frac{m_1 m_2}{r^2}$

$F_g = \frac{G m_1 m_2}{r^2}$

F_g is always attractive.

where F_g is the force of gravity (N)
m_1 and m_2 are the masses (kg)
r is the separation (m)
$G = 6.67 \times 10^{-11} \frac{N \cdot m^2}{kg^2}$

$F_g = mg$

$F_g = \frac{G m_1 m_2}{r^2}$ (m_1: earth, m_2: object)

$g = \frac{G m_1}{r^2}$ where m_1 is the central body. (earth)

MP|579

$m_2 = 65.0 kg$
$m_1 = 7.35 \times 10^{22} kg$
$r = 1.74 \times 10^3 km$
$F_g = ??$

$F_g = \frac{G m_1 m_2}{r^2}$

$F_g = \frac{(6.67 \times 10^{-11} \frac{N \cdot m^2}{kg^2})(7.35 \times 10^{22} kg)(65.0 kg)}{(1.74 \times 10^6 m)^2}$

$F_g \doteq 105 N$

Example
A car weighs 9800N on Earth. How much will it weigh on planet X? Planet X is 3.5 times the earth's mass and has a radius of 1.2 times the earth's radius.

$F_g = \frac{G m_1 m_2}{r^2}$ let F_g' be the weight on planet X.

$F_g' = \frac{G(3.5 m_1) m_2}{(1.2 r)^2}$

$F_g' = \frac{3.5}{(1.2)^2} \frac{G m_1 m_2}{r^2}$

$F_g' = 2.4 \frac{G m_1 m_2}{r^2}$ ← F_g (weight on earth) 9800N

$F_g' = 2.4 F_g$

$F_g' = 2.4(9800N)$

$F_g' \doteq 2.4 \times 10^4 N$

TO DO
① FOP|272-PP (Kepler's law: $K = \frac{r^3}{T^2}$)
② PP|580