Chapter 7
Gravitation

7-1

Planetary Motion and Gravitation

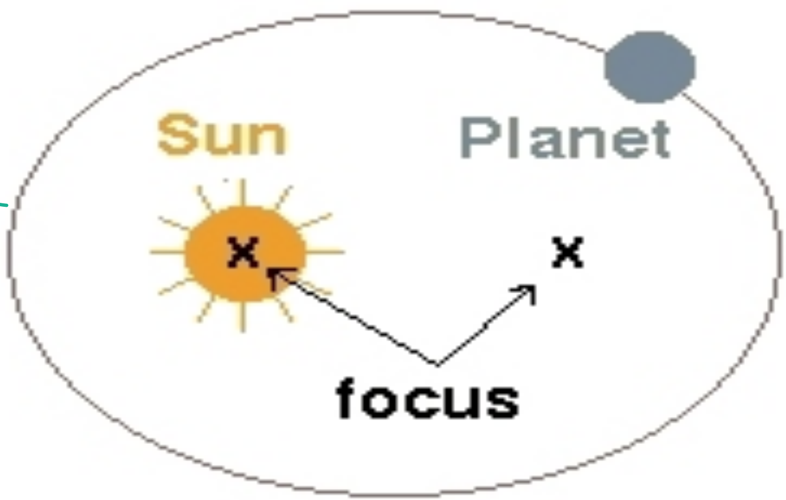
Johannes Kepler

- Believed that the ___sun___ exerted a ___force___ on all of the planets and that the sun was the ___center___ of the system.
- Discovered three laws that ___govern___ the motion of every ___planet___ and every ___satellite___.
  ↳ Anything in orbit around something else
  Ex: Moon and space stations

Kepler's 1st Law

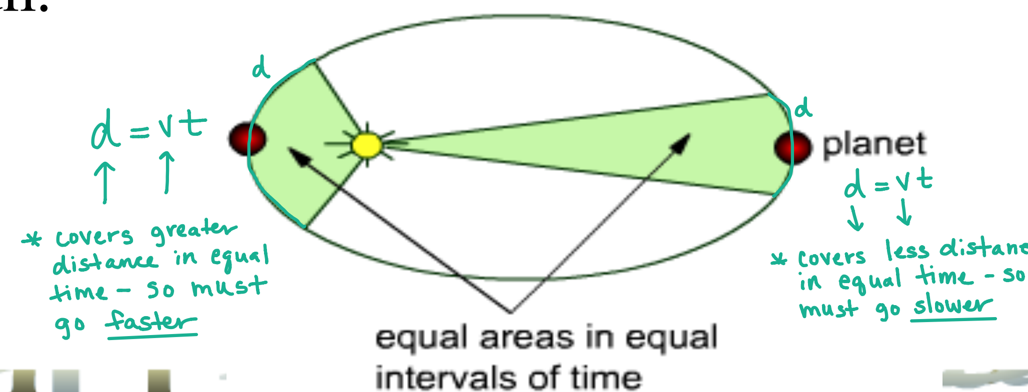
- Planets ______orbit______ in ______elliptical paths______ with the Sun at ______one focus______

* Not a circle
* oval with sun off center



Kepler's 2nd Law

- An imaginary line from the sun to a planet sweeps out equal areas in equal time intervals.
- Meaning – planets move faster when they are closer to the Sun and slower when they are farther from the Sun.



Keplers Second Law

The line from planet to Sun sweeps out equal area in equal time.

For example, if the time taken for the planet to get from A to B is equal to the time for the planet to get from H to I, then the crosshatched areas are equal.

This law is just a consequence of the law of the conservation of angular momemtum.

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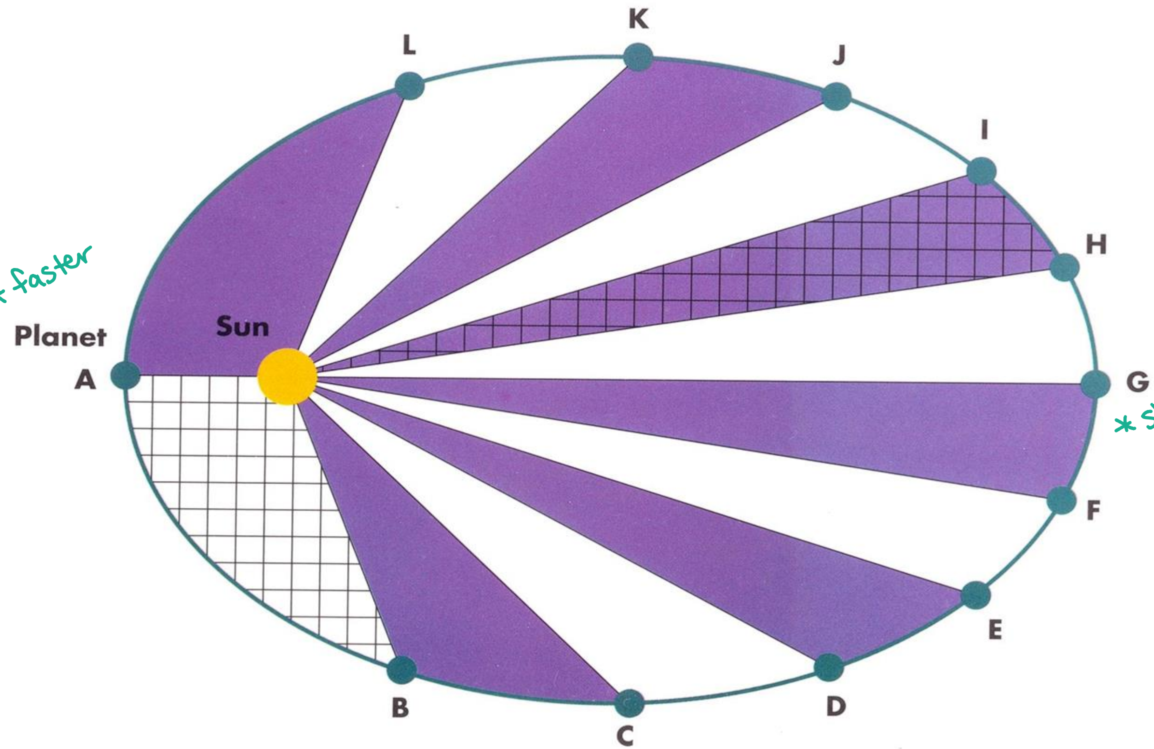
Kepler's second law (Fig. 4-15)



* faster

* slower

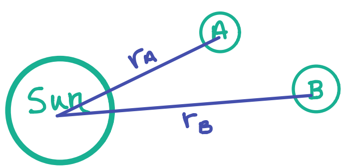
* All equal areas covered in equal times

Kepler's 3rd Law

- The squared quantity of the period of object A divided by the period of object B is equal to the cubed quantity of object A's average distance from the Sun divided by object B's average distance from the Sun.

$$\left(\frac{T_A}{T_B}\right)^2 = \left(\frac{r_A}{r_B}\right)^3$$

* T = period (time for 1 revolution)
* r = orbital radius (center to center distance)



Kepler's 3rd Law

- The third law relates the motion of ___two___ ___bodies___ about a ___center body___.
- EX: 2 planets around the sun
- EX: The moon and a satellite around the Earth

① EX: Galileo measured the orbital sizes of Jupiter's moons using the diameter of Jupiter as a unit of measure. He found that Io, the closest moon to Jupiter, had a period of 1.8 days and was 4.2 units from the center of Jupiter. Callisto, the fourth moon from Jupiter, had a period of 16.7 days. Using the same units that Galileo used, predict Callisto's distance from Jupiter.

② EX: Europa, a satellite of Jupiter, has a period of 3.55 days. How many units is its radial distance?

① $T_I = 1.8$ days
$r_I = 4.2$ units

$T_c = 16.7$ days
$r_c = ?$

$$\left(\frac{1.8}{16.7}\right)^2 = \left(\frac{4.2}{r_c}\right)^3$$

$r_c = 18.5$ units

* Note: Raise each side to the 1/3 power or cube root it to get your variable out of the 3rd power

② $T_E = 3.55$ days

$r_E = ?$

* Use Io info above

$$\left(\frac{1.8}{3.55}\right)^2 = \left(\frac{4.2}{r_E}\right)^3$$

$r_E = 6.6$ units

Newton and Planetary Motion

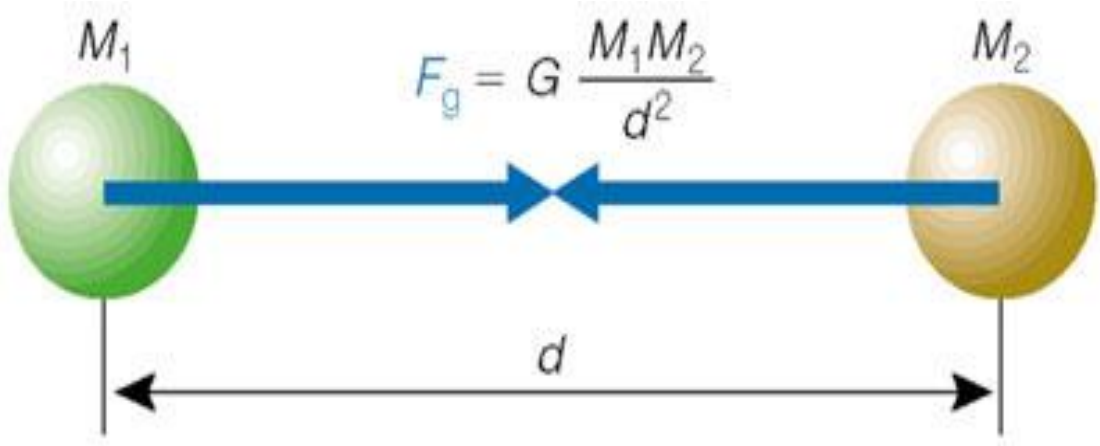
- Gravitational Force – the __force of__ __attraction__ between two objects.
- The force acts in the __direction__ of the line __between the centers__ of the two objects.
- The force is __inversely proportional__ to the __square of the distance__ between the centers of the planet and the Sun: $F \propto \frac{1}{d^2}$ $d\uparrow F\downarrow$
- The force is __directly proportional__ to the __masses__ of the two objects: $F \propto m$ $m\uparrow F\uparrow$

Law of Universal Gravitation

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

$G = 6.67 \times 10^{-11} \frac{N \cdot m^2}{kg^2}$

r = orbital radius (center to center distance)



Credit: Pearson Education, Inc.

Period of a Planet Orbiting the Sun

$$T = 2\pi\sqrt{\frac{r^3}{Gm}}$$

$G = 6.67 \times 10^{-11} \frac{N \cdot m^2}{kg^2}$

r = orbital radius
(center to center distance)

m = mass of the center body
(object being orbitted not object orbitting)

Universal Gravitational Constant

- G = $6.67 \times 10^{-11} \frac{N \cdot m^2}{kg^2}$
- Henry Cavendish calculated this constant in 1798 by finding the gravitational force between two lead spheres, with a known mass and a measured distance between there centers
- Once G was known, the Earth's mass could be calculated, the Sun's mass could be calculated, and the gravitational force between any two objects can be calculated.