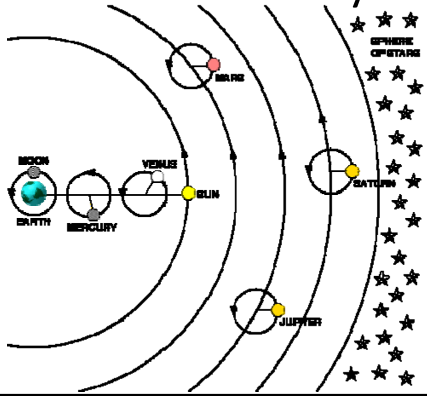
## Old School Solar System




## Copernicus

- Published in 1543 – Poland
- The best available observations did not agree with an Earth centered solar system.

## Copernicus

- The calculations and paths were much easier to understand with the sun at the center.

## Tycho Brahe

- An eclipse on August 21st, 1560 motivated him to become an astronomer. He was 15.

## Tycho Brahe

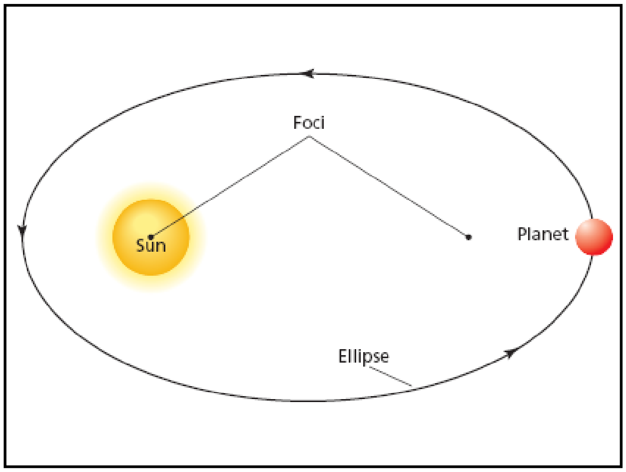
- 20 Years of star maps – Concluded that the planets orbit the sun; the moon and sun orbit Earth. Published in 1590 – Dutch.

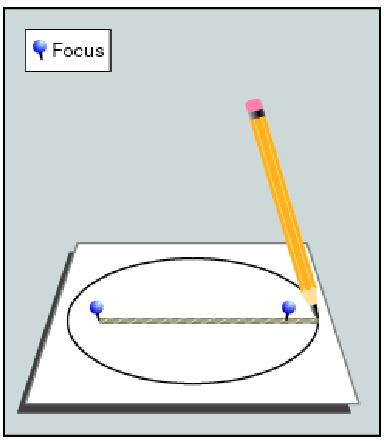
## Johannes Kepler

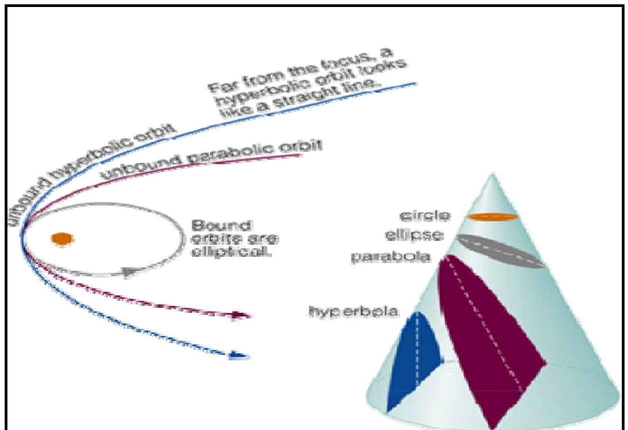
- Worked for Brahe.
- 1601 – Brahe died and left 30 years of data to Kepler.
- Figures out that the sun was the center of the solar system.
- Kepler - German

## Kepler's Laws

- First Law – The paths of the planets around the sun are ellipses with the sun at one focus. Ellipses have two focal points.

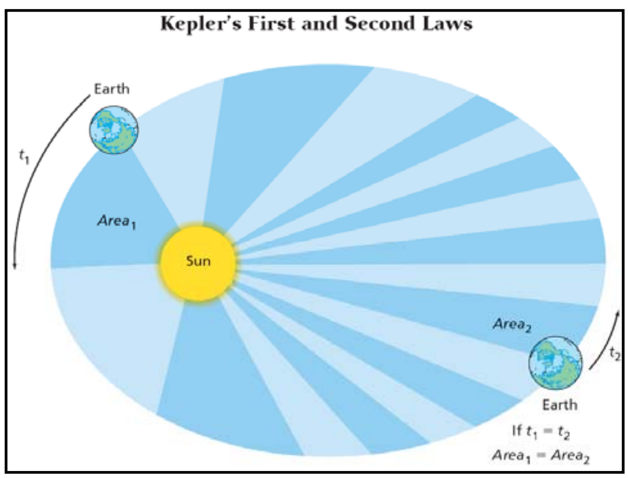



## 2nd Law

- 2nd Law – an imaginary line from the sun to a planet sweeps out equal areas in equal times.
- The planets move faster when they are closer to the sun.



## 3rd Law

- There is a relationship between periods of planets and their distances away from the sun.
- Period – the time it takes for one complete cycle (orbit).
  - We use T –
  - units are [s].

## 3rd Law

- the ratio of the cube of a planet's mean distance, *d,* from the Sun to the square of its orbital period, *t,* is a constant — that is, $d^3/t^2$ is the same for all planets

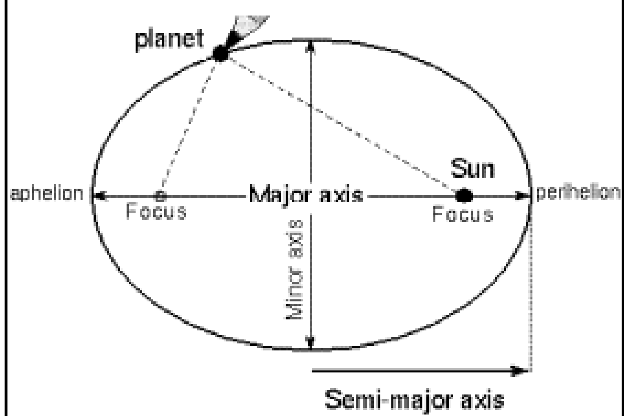
$$\left(\frac{T_A}{T_B}\right)^2 = \left(\frac{r_A}{r_B}\right)^3$$

## Why do Planets Orbit the Sun?

**One Foci will be the center of mass for the system.**

The center of mass of mass for the solar system is close to the surface of the sun.

This is because the sun is about 99.8% of the total mass of the entire solar system!




## Special Vocabulary Terms

**Major axis** – longest length of ellipse

**Semi-major axis** – half of major axis. This is used as average radius for the orbit in Kepler's Laws.

The semi-major axis for the Earth is 149,597,887.5 km (about 93 million miles)

**1 AU (Astronomical Unit)** – average distance from Earth to the Sun. The is used to measure distances in the solar system.

## Special Vocabulary Terms

**Aphelion** – the point of orbit furthest from the Sun
Earth aphelion ≈ 94.5 million miles

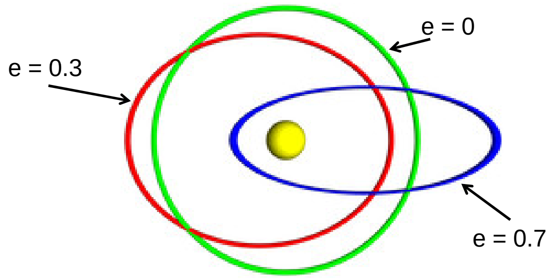
**Perihelion** – the point of orbit closest to the Sun
Earth aphelion ≈ 91.5 million miles

**Apogee** – the point of orbit furthest from the Earth

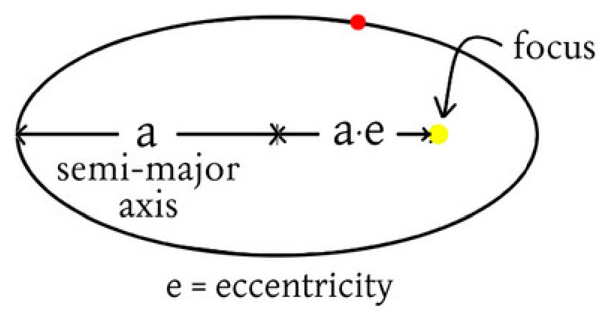
**perigee** – the point of orbit closest to the Earth

## Eccentricity

**Eccentricity (e)** – measure of the shape of the orbit. This ranges from 0 to 1. At 0, it will be a circle and more elliptical the closer eccentricity approaches 1.

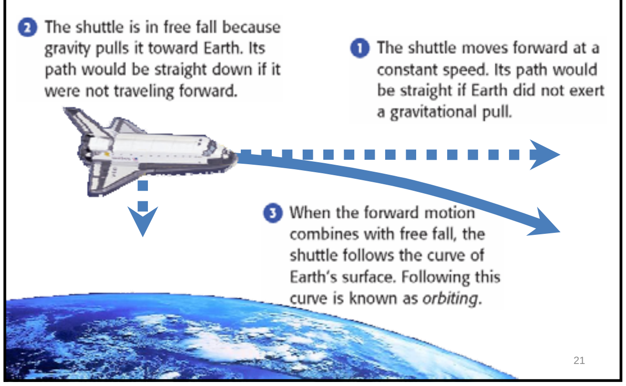



## How Eccentricity affects the Ellipse



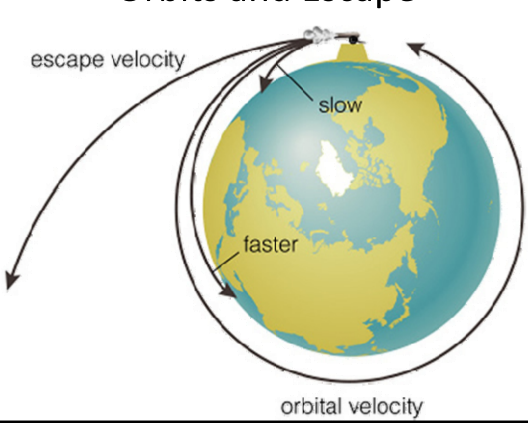

## How Orbiting Works

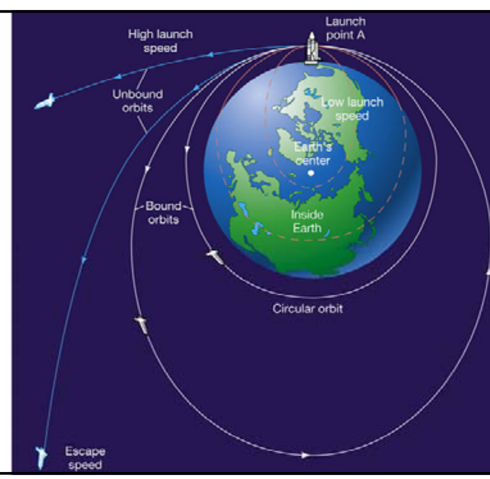
Objects in orbit are said to be always falling.





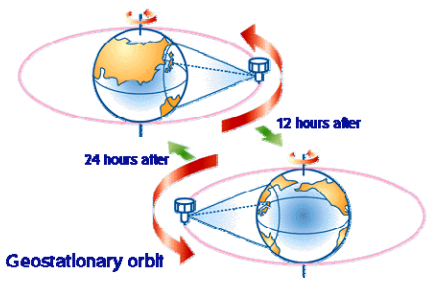
## Orbits and Escape



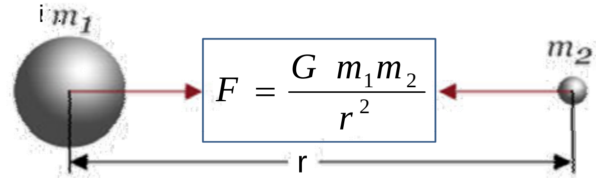
## Geostationary/Geosynchronous Orbit

This occurs when the satellite's period is 24 hours. Above the equator, it will stay above the same location. This is great for weather and communication satellites.




## Law of Universal Gravitation

The gravitational force between any two objects

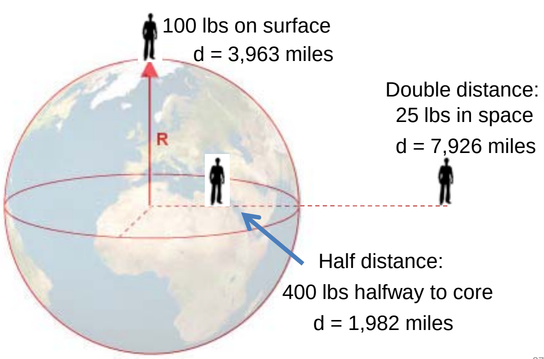



$$F = \frac{G\ m_1 m_2}{r^2}$$

$$G = 6.67 \times 10^{-11} \frac{N\ m^2}{kg^2} \quad or \quad \frac{m^3}{kg \cdot s^2}$$

m = mass of object
r = distance between objects' centers

## Effect of Distance on Gravity

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## Gravity Field

The gravitational field of an object is calculated by:

$$g = \frac{G\ m}{r^2}$$

$$G = 6.67 \times 10^{-11} \frac{N\ m^2}{kg^2} \quad or \quad \frac{m^3}{kg \cdot s^2}$$

m = mass of large body
r = distance from center of the object

## Period of a Planet Orbit

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

$$G = 6.67 \times 10^{-11} \frac{m^3}{kg \cdot s^2}$$

T = Period (seconds)
m = mass of large body being orbited
r = distance between objects' centers

## Velocity of a Planet Orbit

$$V = \sqrt{\frac{Gm}{r}}$$

$$G = 6.67 \times 10^{-11} \frac{m^3}{kg \cdot s^2}$$

v = velocity
m = mass of large body being orbited
r = distance between objects' centers

## Escape Velocity of an Object

$$V_e = \sqrt{\frac{2Gm}{r}}$$

$$G = 6.67 \times 10^{-11} \frac{m^3}{kg \cdot s^2}$$

v = velocity
m = mass of large body being orbited
r = distance between objects' centers

## Useful Information

Mass of Earth = $5.97 \times 10^{24}$ kg

Mass of Sun = $1.99 \times 10^{30}$ kg

Mass of Moon = $7.35 \times 10^{22}$ kg

Radius of Earth = $6.38 \times 10^{6}$ m