Geocentric/Heliocentric

- Until Copernicus and Galileo, it was believed that Earth was the center of the solar system. Ptolemy even proposed an explanation of the planets' paths (epicycles)as they orbited the Earth.
- In the 1500s, Copernicus fought to establish a heliocentric model, where the Sun was center and Earth was an orbiter of the Sun. Galileo was able to see Venus through the new telescope and show that its phases were better explained by heliocentrism.

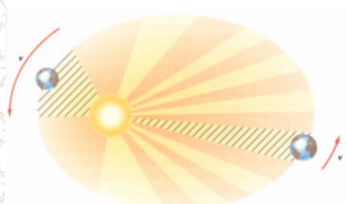
Kepler's Laws

Using Brahe's data of the paths of objects in space, Kepler proposed three laws of planetary motion.

1. The paths of planets are ellipses, with the sun at one focus.
2. An imaginary line from the sun to the planet sweeps out equal areas in equal time intervals.

Kepler's Laws

Planets move faster when they are closer to the sun.



Kepler's Laws

3. The square of the ratio of the periods of any two planets revolving about the sun is equal to the cube of the ratio of their average distances from the sun, or

$$\frac{T_A^2}{T_B^2} = \frac{r_A^3}{r_B^3}$$

Example

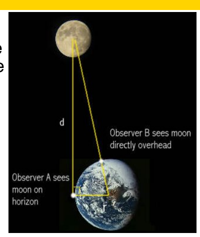
- Mars takes 684 Earth days to complete one revolution around the Sun.

1. What evidence is there that Mars is farther from the Sun than Earth?
2. If the distance from the Earth to the Sun is 1 AU, how far is Mars from the Sun?

Astronomical Distances

Scientists have long desired to know the distances to astronomical objects. The following methods have been used in the past:

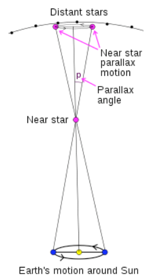
Parallax - when an object is viewed from two different positions, the object's location is different. Through these sightlines, a triangle can be formed that determines the distance between the observer and the object.



In order for parallax to work, the object has to be much closer than the objects behind it. The objects behind it must seem that they don't move when the position is changed.

Parallax

- To take a parallax measurement, two observers need to record the position of an object at the same time. The larger the distance between the two people, the better the measurement.
- For some distance objects, parallax is measured by taking measurements 6 months apart.
- For triangles of these kind, the distance between the observers and the angle of parallax need to be found.



Other methods of distances

With newer technology, radio waves can be fired off at objects in space. The radio waves will travel to the object, bounce off and return to the source. Measuring the time difference between when it was fired and retrieved can be used to determine the distance.

Extremely far off objects can be found by red shift. In this case, because the universe is expanding and the Doppler Effect, stars moving from us appear more red than they are. The difference between what we think they are and their redness can be used to determine distances.

Universal Gravitation

Newton picked up on Kepler's work and said that the force, F, on the planet resulting from the sun must vary inversely with the square of the distance, or

$$F \sim \frac{1}{d^2}$$

This means, doubling the distance between celestial objects means decreasing the gravitational force by 1/4.

Universal Gravitation

Newton, later working on the idea of gravity, said that all objects that have mass would attract one another. Thus, the force of attraction would also depend on the masses of the two objects. The following equation was developed:

$$F = G \frac{m_A m_B}{d^2}$$

However, Newton didn't know what G, his universal gravitational constant was.

Gravitational Constant

Cavendish used small masses and tension in a string to determine the universal gravitation constant to be $G = 6.67 \times 10^{-11}\ Nm^2/kg^2$

Newton's Cannon

The curvature of the Earth is 4.9 m vertical for every 8 km horizontal.

Newton believed if a cannonball was going fast enough, the cannon would fall the same amount as the Earth fell away from it. This would keep the object in orbit, if there were no friction.

Satellites

By combining Newton's Law of Universal Gravitation, centripetal acceleration and force, it is possible to solve for the speed of a satellite:

$$v = \sqrt{\frac{Gm_E}{r}}$$

And the period:

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

Gravitational Field

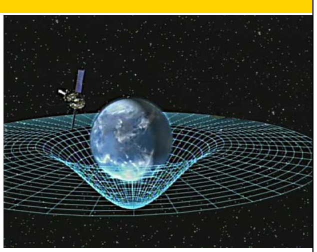
As you know, the acceleration due to gravity at the surface of the Earth is 9.8 m/s^2. However, as a spaceship gets farther from the surface, the gravitational field is reduced by the following equation. The gravitational field (a) at any point above the Earth's surface can be calculated by:

$$a = g\left(\frac{r_E}{d}\right)^2.$$

As we have talked about before, the amount of gravity is dependent on the square of the distance.

Einstein's Theory of Gravity

Einstein believed that gravity was not a force, but an effect of space itself. Massive objects in space curve the space, which causes the objects to accelerate the way they do.



This general theory of relativity has been upheld by all tests trying to disprove it.

Two kinds of masses

Inertial mass is the mass of the object in relation to its motion. The inertial mass is seen when an object in the back of the truck slides backwards when the truck accelerates.

Gravitational mass is the mass of an object in relation to the mass of other objects. This mass is seen when the same object slides backwards as the truck goes up a hill.

These two masses have been proven to be equal.