Objectives

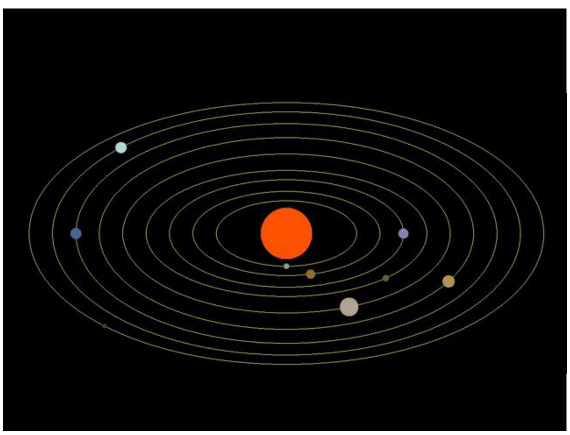
- **Describe** early models of our solar system.
- Examine the modern heliocentric model of our solar system.
- Relate gravity to the motions of celestial bodies.

Vocabulary

– retrograde motion
– astronomical unit
– perihelion
– aphelion
– eccentricity

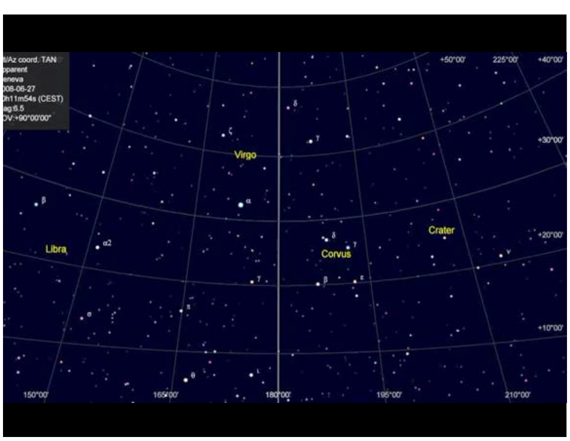
Overview of Our Solar System

- Earth is one of nine planets revolving around, or orbiting, the Sun.
- All the planets, as well as most of their moons, also called satellites, orbit the Sun in the same direction, and all their orbits, except Pluto's, lie near the same plane.
- The planets of our solar system have various sizes, surface conditions, and internal structures.



Early Ideas

- When viewed from Earth, the planets slowly change position each night relative to the position of the stars.
- Ancient astronomers assumed that the Sun, planets, and stars orbited a stationary Earth in what is now known as a geocentric model, meaning "Earth centered."



Early Ideas

- Some aspects of planetary motion were difficult to explain with a geocentric model.
  - The normal direction of motion for all planets, as observed from Earth, is toward the east.
  - Retrograde motion is when a planet occasionally will move toward the west across the sky.

SECTION 29.1

Overview of Our Solar System

Early Ideas

- In 1543, Polish scientist Nicolaus Copernicus suggested that the Sun was the center of the solar system.
  - In a Sun-centered, or heliocentric, model, the inner planets move faster in their orbits than the outer planets do.
  - As Earth bypasses a slower-moving outer planet, it appears that the outer planet temporarily moves backward in the sky.

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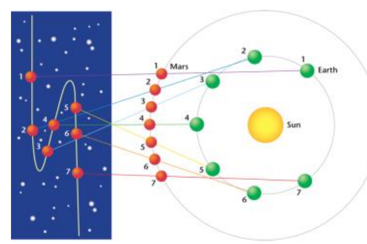
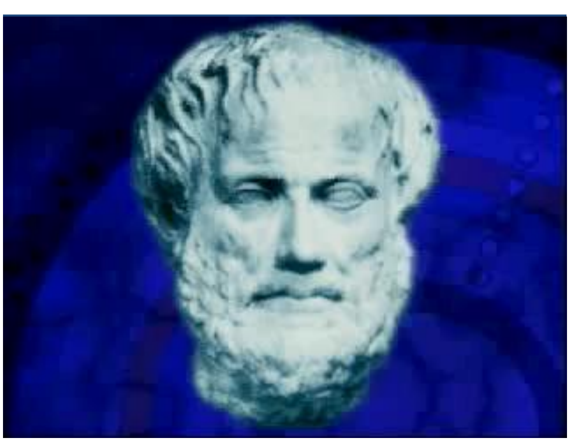
Overview of Our Solar System

Early Ideas

Mars appears to move from east to west (positions 3 and 4) for a short time during its retrograde motion. Retrograde motion is similar to passing a slower car in the freeway. It appears that the slower car is moving backward relative to the background. (not to scale)





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Overview of Our Solar System

Early Ideas

Kepler's First Law

- From 1576–1601, Danish astronomer Tycho Brahe made accurate observations of planetary positions.
- Using Brahe's data, Johannes Kepler demonstrated his first law which states that each planet orbits the Sun in a shape called an ellipse.
- An ellipse is an oval shape that is centered on two points called the foci instead of a single point, as in a circle.

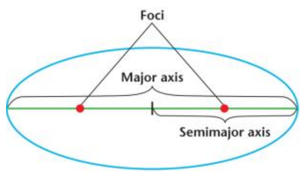
SECTION 29.1 Overview of Our Solar System

Early Ideas

Kepler's First Law

– The major axis, the maximum diameter of the ellipse, is the line that runs through both foci, one of which is always the Sun.

– Half of the length of the major axis is called the semimajor axis and is equal to the average distance between the Sun and the planet.



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Early Ideas

Kepler's First Law

– An astronomical unit (AU), 1.496 × 10^8 km, is the average distance between the Sun and Earth.

– The average distances between the Sun and each planet are measured in astronomical units.

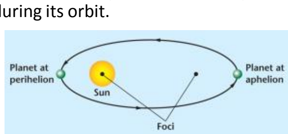
SECTION 29.1 Overview of Our Solar System

Early Ideas

Eccentricity

– A planet in an elliptical orbit is not at a constant distance from the Sun.

- Perihelion is when a planet is at the closest point to the Sun in its orbit.
- Aphelion is when a planet is farthest point from from the Sun during its orbit.



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Early Ideas

Eccentricity

– Eccentricity, which is the ratio of the distance between the foci to the length of the major axis, defines the shape of a planet's elliptical orbit.

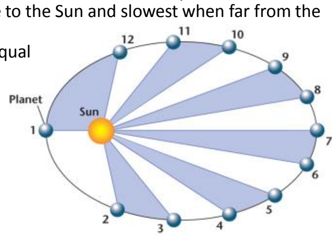
– The orbital period is the length of time it takes for a planet or other body to travel a complete elliptical orbit around the Sun.

SECTION 29.1 Overview of Our Solar System

Early Ideas

Kepler's Second and Third Laws

– Kepler's second law states that because a planet moves fastest when close to the Sun and slowest when far from the Sun, equal areas are swept out in equal amount of time.



SECTION 29.1 Overview of Our Solar System

Early Ideas

Kepler's Second and Third Laws

– Kepler also found that the square of the orbital period (P) equals the cube of the semimajor axis of the orbital ellipse (a).

– Kepler's third law states $P^2 = a^3$, where P is a unit of time measured in Earth years, and a is a unit of length measured in astronomical units.

– Italian scientist Galileo Galilei proved, by discovering four moons orbiting the planet Jupiter, that not all celestial bodies orbit Earth, and therefore, Earth is not necessarily the center of the solar system.

SECTION 29.1 — Overview of Our Solar System

Early Ideas

Kepler's Second and Third Laws

- In 1684, English scientist Isaac Newton published a mathematical and physical explanation of the motions of celestial bodies.
- Newton's concepts included the law of universal gravitation, which provided an explanation of how the Sun governs the motions of the planets.

SECTION 29.1 — Overview of Our Solar System

Gravity and Orbits

- Through observations, Newton realized that any two bodies attract each other with a force that depends on their masses and the distance between the two bodies.
- The force grows stronger in proportion to the product of the two masses, but diminishes as the square of the distance between them increases.

SECTION 29.1 — Overview of Our Solar System

Gravity and Orbits

Gravity

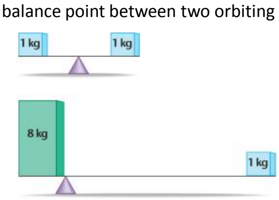
- Newton's law of universal gravitation states that every pair of bodies in the universe attract each other with a force that is proportional to the product of their masses and inversely proportional to the square of the distance between them.

SECTION 29.1 — Overview of Our Solar System

Gravity and Orbits

Center of Mass

- Newton also determined that each planet orbits a point between it and the Sun called the center of mass.
- The center of mass is the balance point between two orbiting bodies.
- If one of two bodies orbiting each other is more massive than the other, the center of mass is closer to the more massive body.



SECTION 29.1 — Overview of Our Solar System

Section Assessment

1. Match the following terms with their definitions.

D retrograde motion
B astronomical unit
A perihelion
C aphelion

A. the closest point to the center of mass in an elliptical orbit
B. a distance equal to the average distance between Earth and the Sun
C. the farthest point from the center of mass in an elliptical orbit
D. when a plant moves east to west across the sky

SECTION 29.1 — Overview of Our Solar System

Section Assessment

2. What is eccentricity?

Eccentricity, which is the ratio of the distance between the foci to the length of the major axis, defines the shape of a planet's orbit.

Section Assessment

3. Identify whether the following statements are true or false.

__false__ If the distance between the Moon and Earth was greater, the gravitational force would be greater as well.

__true__ The center of mass between a plant and the Sun can be within the Sun.

__true__ Planets move faster when they near the perihelion of their orbit.

__true__ Galileo proved that not all celestial bodies orbit Earth.