

# Orbital Dynamics

## Kepler Laws of Planetary Motion

### First Law

Planets orbits are in the shape of an ellipse

### Second Law

As planets move around the Sun in its orbit it covers equal areas in equal times.

### Third Law

The time a planet takes to complete one orbit is related to its average distance to the Sun

**-ellipse** – closed, symmetric curve shaped like an oval. The sum of the distances of any point on an ellipse from two fixed points (called the foci) remains constant no matter where the point is on the curve.

**-eccentricity** – the more eccentric the orbit the less circular the orbit is. A measure of how far a planet's orbit about the Sun is from being circular. An eccentricity of 0 is a perfect circle while a 1 is a straight line.

### eccentricity examples

Venus  $e = 0.0068$

Earth  $e = 0.0167$

Neptune  $e = 0.0112$

Jupiter  $e = 0.048$

Mercury  $e = 0.205$

Pluto  $e = 0.248$

Halley's Comet  $e = 0.967$

Comet Hale-Bopp  $e = 0.995$

**-orbital plane** – also called the ecliptic. It is a plane formed by the path of the Earth around the Sun.

**-inclination** – the angle between the orbital plane of the solar system and the actual orbit of an object around the Sun's equator.

### inclination examples

Venus -  $3.86^\circ$

Earth -  $7.155^\circ$

Neptune -  $6.43^\circ$

Jupiter -  $6.09^\circ$

Mercury -  $3.38^\circ$

Pluto -  $17.14^\circ$

Halley's Comet -  $162.3^\circ$

Comet Hale-Bopp -  $89.4^\circ$

**-axial tilt** – cause of seasons. Objects tilt compared to orbital plane or path around star. The angle in degrees the axis of a planet is tilted relative to a line perpendicular to the planet's orbit around the Sun. Greater the angle of tilt the greater the difference in solar energy.

Earth 23.5

Mars 25

Uranus 98

Jupiter 3

Mercury 2.1

Venus 177.4

-**precession** – slow motion of the axis of the Earth around a cone, one cycle is about 26,000 years, due to gravitational tugs by the Sun, Moon, and major planets.

### **How Do Earth's Orbital Variations Affect Climate?**

#### **The Earth's Axial Tilt and the Seasons**

- The Earth's axis of rotation is tilted 23.5 from perpendicular
- It is this tilt that explains the different seasons on Earth
- During the course of the Earth's orbits around the Sun, certain areas of the Earth are tilted toward the sun and experience summer while others are tilted away from the Sun and experience winter.
- That is why when it is summer in Colorado (the Northern Hemisphere) it is winter in Australia (the Southern Hemisphere).

#### **Other Factors that affect the Earth's climate**

- Over periods of thousands of years, changes in the following three areas affect the Earth's climate:
  - Eccentricity
    - Obliquity
    - Precession
- Together these things are called the Earth's orbital parameters

#### **Eccentricity**

- Remember, the Earth's eccentricity is very low, almost zero, which means the Earth's orbit is nearly a perfect circle.
- The distance between the Earth and the Sun varies very little throughout the course of a year (3.3%)
- The Earth is closest to the Sun on January 5<sup>th</sup>- perihelion. It is furthest from the Sun on July 5<sup>th</sup>- aphelion

#### **Obliquity**

- The tilt of the Earth axis relative to the plane of its orbit is called the Obliquity.
- A smaller obliquity would mean warmer winters and cooler summers in the Northern Hemisphere.
- The Earth's obliquity changes over a period of about 40,000 years.

#### **Precession**

- The gravitational pull of the Sun, Moon, and other planets on the Earth causes the Earth to have a slight wobble .

#### **Milankovitch Cycles**

- Makes long term predictions about the Earth's climate based upon the combined affects of Eccentricity, Obliquity, and Precession.

