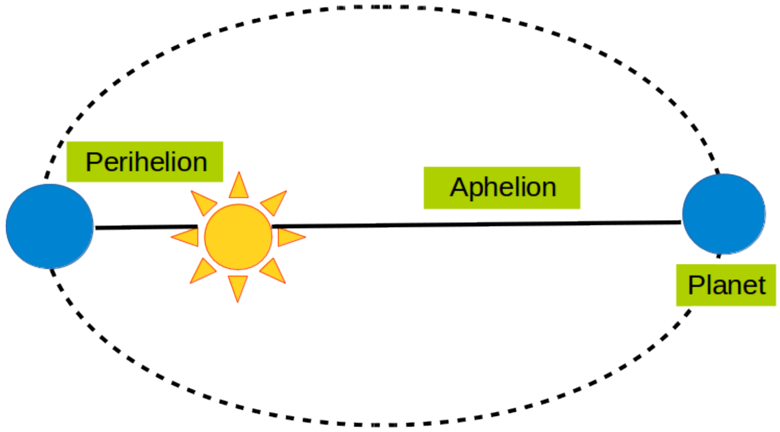
Additional Material for Kepler's Laws

In astronomy, Johannes Kepler has proposed three laws of planetary motion.

Here are the three Laws:

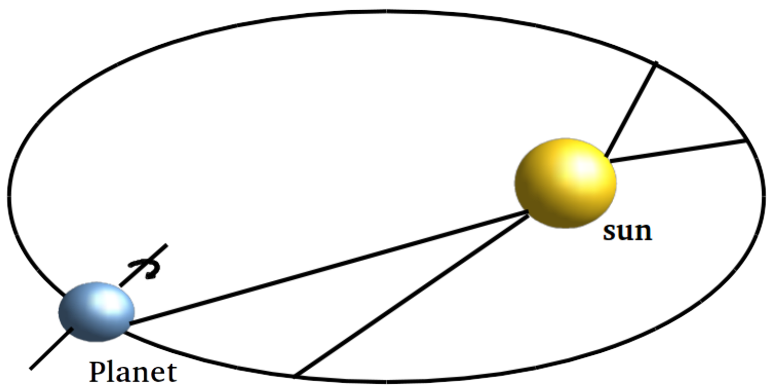
1) Law of orbits - All planets move in elliptical orbits with the Sun situated at one of the foci.



The ellipse is a closed curve. It is a special case of the circle. An ellipse is traced out when the planets revolve around the sun on their own orbit.

Perihelion is the position on the orbit where planets are closer to sun. Aphelion is the position on the orbit where planets are farthest away from the sun.

2) Law of areas - The line that joins any planet to the sun sweeps equal areas in equal intervals of time.



3) Law of periods - The square of the time period of the planet is directly proportional to the cube of the semimajor axis of its orbit.

$$T^2 \, \alpha \, \boldsymbol{a^3}$$

T is a time period, **a** is semimajor axis.

$\mathbf{T^2 = a^3 \times (4\pi^2 / GM)}$

Here **($4\pi^2$ / G)** is constant and the value of gravitational constant

G is $6.674 \times 10^{-11}\,Nm^2/kg^2$.

This law comes from the observations that planets appear to move slower when they are farther from the sun than when they are nearer.

Eccentricity: It is the measure of how an orbit of a celestial object deviates from a circle.

Example 1: Find the perihelion and aphelion distances from the Sun to planet Mars, if the following data is given : eccentricity is 0.093, semimajor axis as 1.52 AU.

Solution 1: Formula to calculate perihelion is :

$R_p = a(1-e)$

$R_p = 1.52 \times (1- 0.093)$

$= \mathbf{1.378\ AU}$

Formula to calculate aphelion is :

$R_a = a(1+e)$

$R_a = 1.52 \times (1+0.093)$

$= \mathbf{1.661\ AU}$

Example 2: Determine Jupiter's mass, if it orbits at an orbital radius of 4.218 x 10^8 m for every 151200 seconds.
a = 4.218 x 10^8 m, T = 151200 s, G = 6.674 x 10^{-11}N-m^2/kg^2.

$$M = \frac{4\pi^2 a^3}{GT^2}$$

$$M = \frac{4 \times (3.14)^2 \times (4.218 \times 10^8)^3}{6.674 \times 10^{-11} \times (151200)^2}$$

$$M = \frac{4 \times 9.859 \times 75.04 \times 10^{24}}{6.6726 \times 10^{-11} \times 2.29 \times 10^{10}}$$

$$M = 1.94 \times 10^{27}\, Kg$$

Earth's Satellites

Moon is the natural satellite of Earth. Motion of Moon around the earth is similar to the motion of planets around the Sun. The orbit of satellites around the earth are circular or elliptical. The time period of Moon on it's orbit to go around the earth is about 27.32 days. Hence the Kepler's Laws of planetary motion are applicable to Earth's Satellites.

Kepler's laws give basic rules that help to understand the movement of a satellite.

From the first law of planetary motion, a satellite in an orbit, that revolves around a celestial object in an elliptical orbit will always be situated at one of its foci.

Aphelion and Perihelion are two important positions on an elliptical orbit which are used to describe the movement of a satellite. These distances are measured from the surface of the satellite.

From the second law of planetary motion, in an elliptical orbit a satellite sweeps equal areas in equal times. At the aphelion, the satellite is at its slowest speed and at the perihelion its speed is fastest. Satellite operating companies use this law for their advantage. They position the satellite in the orbit in such a way that it stays there for maximum time and sends signals to a particular region.

The third law of planetary motion shows that the orbital period of a satellite in an orbit depends on its distance from the Earth and some constant that depends on Earth's parameters. If the distance between satellite and the Earth is large, the orbital period reduces and vice versa.

The content for this additional material is taken from NCERT 11th class physics textbook.