SATELLITE ORBITS

Types:

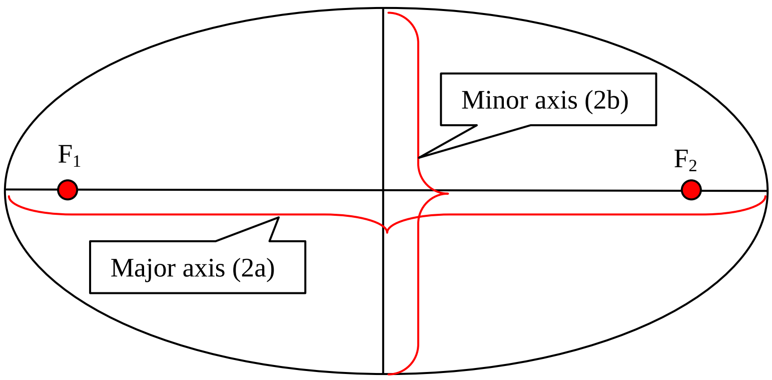
- Elliptical in general

- Geostationary
- Inclined
- Polar
- Low and Medium Earth Orbits (LEOs and MEOs)

Laws Governing Satellite Motion:

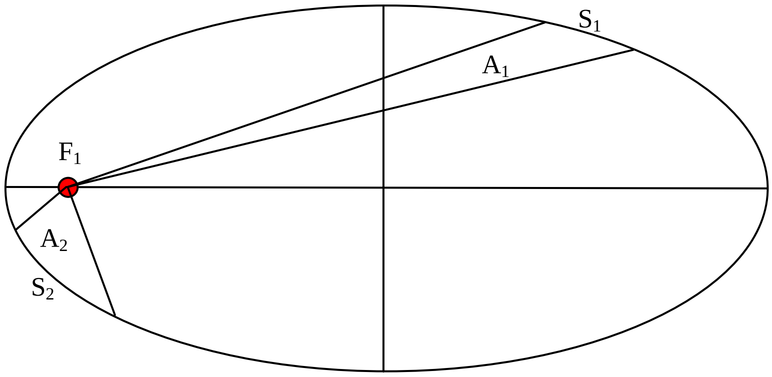
Kepler's laws (1609 – 1619)

- ***First Law***
  - The path followed by the satellite (e.g. Earth) around the primary (e.g. Sun) is an ellipse. The ellipse has two focal points. The centre of mass (barycentre) is always centred at one of the foci.



- ***Second Law***

  - For equal time intervals, the satellite sweeps out equal areas in its orbital plane, focused at the barycentre.



Assuming the satellite travels distances S_1 and S_2 in 1 second, then the areas A_1 and A_2 will be equal.

- ***Third Law***

  - The square of the periodic time of orbit is proportional to the cube of the mean distance between the two bodies (satellite and the primary).

The mean distance of the satellite is equal to the semi-major axis "a".

$$a^3 = \frac{\mu}{\omega^2} \qquad \ldots\ldots \qquad (1)$$

where μ is the earth's gravitational constant and is given by: 3.986005 x 10^{14} m^3/s^2
and ω is the mean angular velocity of the satellite, which is related to the period by: $\omega = \frac{2\pi}{T}$.

$$T^2 = \left(\frac{4\pi^2}{\mu}\right) a^3$$

Example 1:

Calculate the radius of a circular orbit for which the period is one day.

Solution

$$\omega = \frac{2\pi}{1\ day} = 7.272\ 10^{-5}\ rad/\sec$$

Using μ = 3.986005 x 10^{14} m^3/s^2

$$\therefore a = \left(\frac{\mu}{\omega^2}\right)^{1/3} = 42241...\ km$$

Newton's laws of motion characterised the forces that give rise to Kepler's laws.

- ***First Law***
    - **Every body continues in its state of rest or uniform motion in a straight line unless it is**

compelled to change that state by forces impressed on it.

- ***Second Law***
  - **The rate of change of momentum of a body is proportional to the force impressed on it and is in the same direction as that force.**
    Mathematically → $\sum F = m\ddot{r}$

- ***Third Law***
  - **To every action there is an equal and opposite reaction.**

Newton also postulated the law of gravitation, which states that any two bodies attract one another with a force proportional to the product of their masses and inversely proportional to the square of the distance between them.

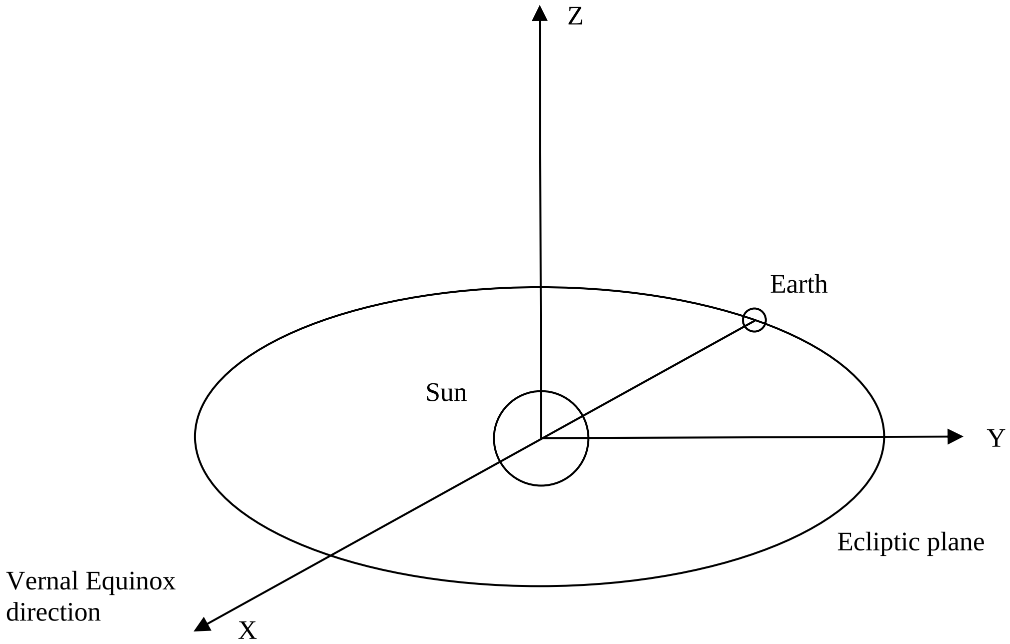
Mathematically → $F = \frac{GMm}{r^2}\,\hat{r}$

G is the gravitational constant = 6.67 x 10^{-8} dyn.cm^2/g^2

Newtons & Kepler's laws completely explain the motion of planets around the sun (and satellites around the earth).

Coordinate Systems

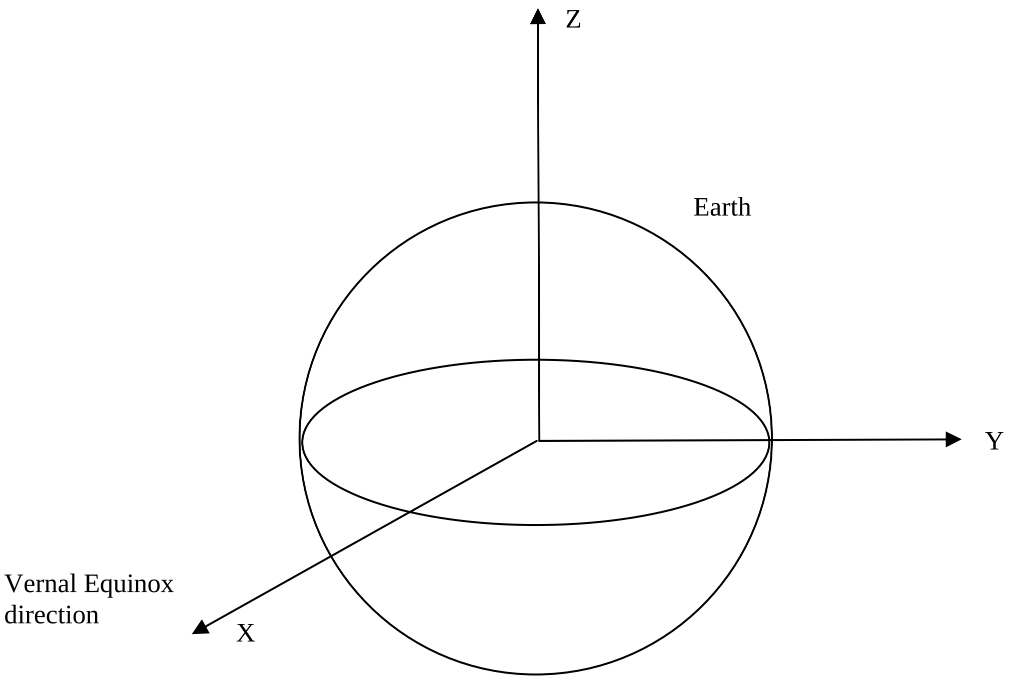
- Heliocentric Ecliptic Coordinate System
- Geocentric Equatorial Coordinate System
- Right ascension-declination Coordinate System
- Perifocal Coordinate System



Heliocentric Ecliptic Coordinate System

This coordinate system is used to describe the motion of planets around the sun.

Origin → Centre of the sun
XY plane → Ecliptic plane, which is the plane of the earth's revolution round the sun.
X axis → The line joining the origin and the geocentre in the direction of vernal equinox.



Geocentric Equatorial Coordinate System

Origin	→	**Geocentre (centre of earth)**
XY plane	→	**Equator (fundamental plane)**
Positive X axis	→	**In the direction of vernal equinox**
Positive Y axis	→	**To the east of the vernal equinox**
Positive Z axis	→	**In the direction of the north pole**