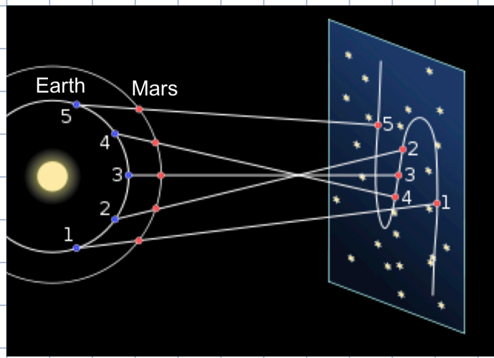
Copernicus proposed that the motion of Mars could only be explained if both the earth & Mars moved around the sun.



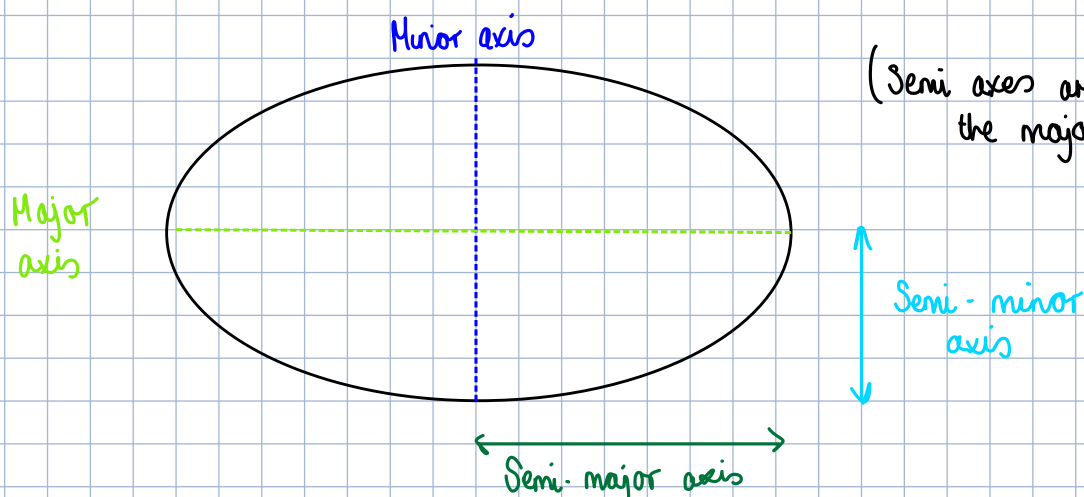
Planetary Motion :

Brahe - collected astronomical data on planets

→ Kepler - took the data & worked on laws (based of observation)

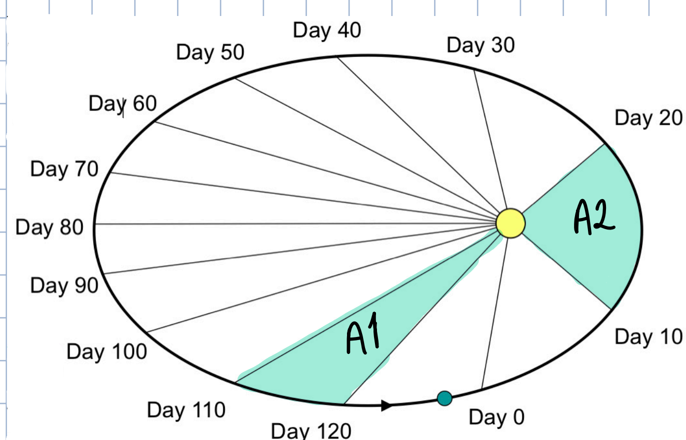
↳ Newton developed mathematical explanation

Keplers 1st Law : 'Planets trace ellipses around the sun'



(Semi axes are half the majors & minors)

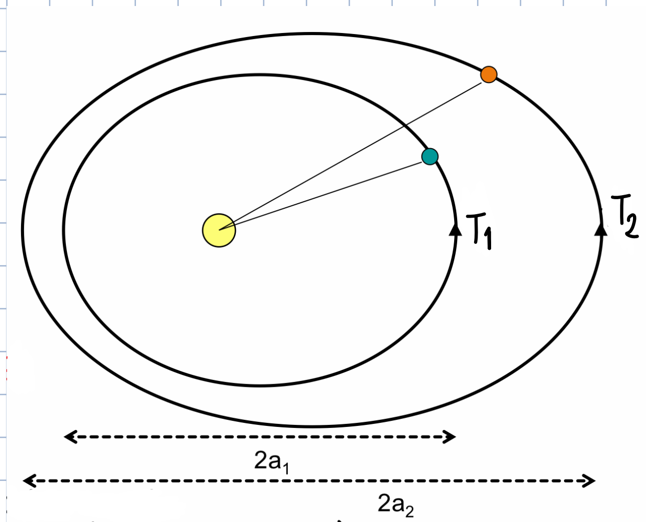
Keplers 2nd Law : 'the line joining a planet to the sun sweeps out equal areas in equal intervals of time'



$\frac{dA}{dt}$ = constant.

A1 = A2

Keplers 3rd Law : 'the square of the orbital period of a planet is proportional to the cube of the semi-major axis of it's orbit'



$$\frac{T_1^{\,2}}{T_2^{\,2}} = \frac{a_1^{\,3}}{a_2^{\,3}}$$

satellites aligned to sidereal day

T = sidereal orbital period

time for stars to come back to same position in sky

T in years

a in astronomical units

1AU = 149×10^6 km

Sidereal = 360° (23 56' for earth)

Solar = ~361° (24 for earth)

time taken for sun to come back to same place

Ellipse Nomenclature :

Apo means 'far' → furthest point from body

Peri means 'close' → closest point

Gee = earth , lune = moon , helion = sun , apsis = non-specific

e.g Apolune = furthest point in orbit around the moon

Orbit Definition : 'closed or recurring path that spacecraft or other body follows around another body'

if e = eccentricity of ellipse

e = 0 = circular

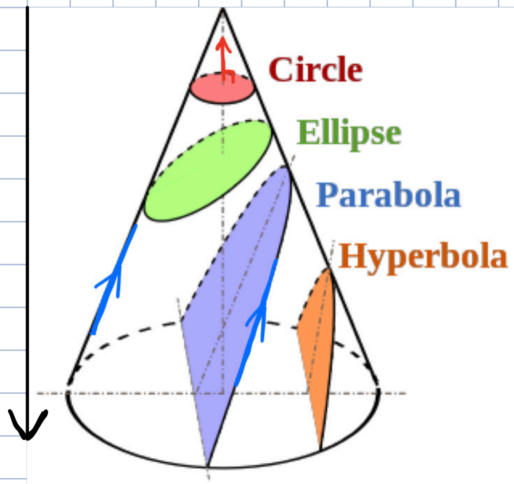
e < 1 = ellipse

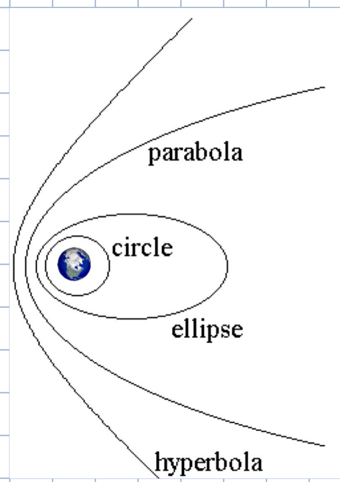
e = 1 = parabola

e > 1 = hyperbola

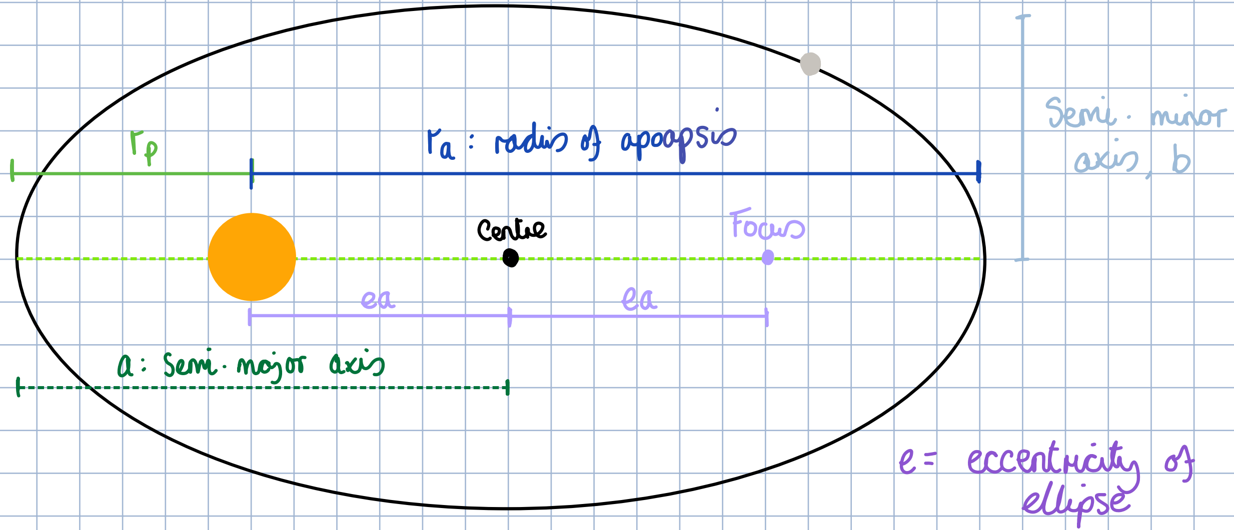
These are defined by conic sections :

Increasing velocity leads to increasing eccentricity





Equations :



Apoapsis Distance $r_a = a(1+e)$ + → larger ∴ furthest distance

Periapsis Distance $r_p = a(1-e)$

Semi - major axis $a = (r_a + r_p)/2$

Eccentricity $e = \dfrac{ea}{a} = \dfrac{(r_a - r_p)}{(r_a + r_p)}$

Distance Centre to Focus $C_F = ea = a - r_p$

Area of Ellipse $= \pi a b$

Semi - minor axis $b = a\sqrt{1-e^2}$

Equation of Ellipse $= \dfrac{x^2}{a^2} + \dfrac{y^2}{b^2} = 1$

Newton's Universal Law of Gravitation:

Force exerted on mass m_1 by m_2:

vector r

$$\boxed{F_{1,2} = -\frac{Gm_1m_2}{r^2}\hat{r}_{12} = \frac{Gm_1m_2}{r^3}\underline{r}_{12}}$$

attractive force

$r = |\underline{r}_{12}|$

$G = 6.67259 \times 10^{-11}\ m^3\,kg^{-1}\,s^{-2}$

Orbital Energy:

Total energy of system constant:

$$E = KE + PE$$

for space, written as: $E = KE + U$

potential defined as 0 at infinity so is always -ve

from centripetal force & N2:

$$F = ma \rightarrow \frac{GMm}{r^2} = \frac{mv^2}{r}$$

$$K = \frac{1}{2}mv^2 = \frac{1}{2}\frac{GMm}{r}$$

$$E = \frac{1}{2}mv^2 - \frac{GMm}{r}^{*} = \frac{GMm}{2r} - \frac{GMm}{r}$$

$$\boxed{E = -\frac{GMm}{2r}}$$

$\longrightarrow$ total energy $\uparrow$ for $\uparrow r$ (as -ve)

$\therefore$ larger radii orbits have higher total energy

* $U = -\int \vec{F} \cdot \vec{dr}$

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

$$U = -\int_{\infty}^{r} -\frac{GMm}{r^2}\,dr = -\frac{GMm}{r}$$

Energy form changes form throughout orbit:

$\rightarrow$ sum constant but at periapsis, $\uparrow KE$, $\downarrow U$ & at apoapsis $\uparrow U$, $\downarrow KE$