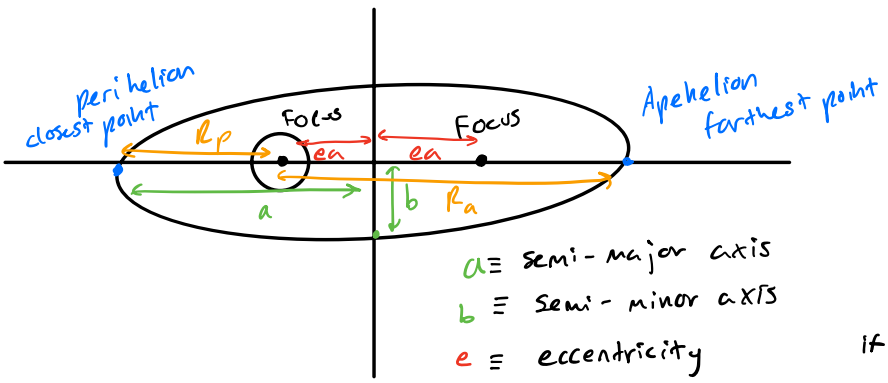
OH TBD

probably T R 1-2 pm 503 ERB

Kepler's Laws

- geometric description for empirical observations
  - -> later proven with EOM / dynamics

Law 1: planets move in elliptical orbits with one focus at the sun



a ≡ semi-major axis

b ≡ semi-minor axis

e ≡ eccentricity

if circular → e = 0

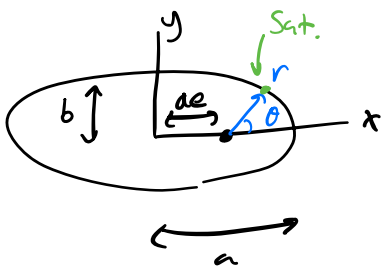
$\therefore R_a = a(1+e)$ sun to aphelion

$R_p = a(1-e)$ sun to perihelion

object	close	far
earth	perigee	apogee
moon	perilune	apolune
Jupiter	perijove	apojove
general	periapse	apoapse

Ellipse details

equation $\left(\frac{x}{a}\right)^2 + \left(\frac{y}{b}\right)^2 = 1$ (1)



r ≡ dist. from focus to curve

θ ≡ angle from x axis to $\bar{r}$ vector

$\therefore x = ae + r\cos\theta$, $y = r\sin\theta$ (2)

use $b = a\sqrt{1-e^2}$ (3)

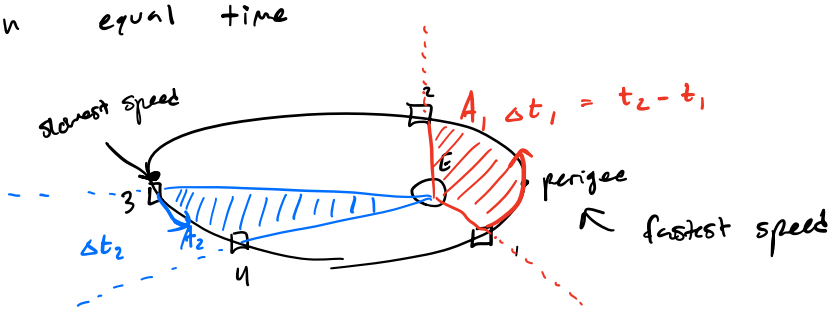
Sub (2) & (3) into (1) → quadratic $r(\theta)$

$\therefore$ 2 solutions: choose + root

$$r(\theta) = \frac{a(1-e^2)}{1+e\cos\theta}$$

r, θ used more in dynamics soon

Law 2: Planets (or satellites) sweep equal areas of the ellipse in equal time



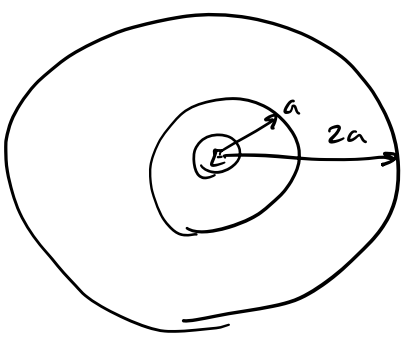
$\therefore$ if $A_1 = A_2$
then $\Delta t_1 = \Delta t_2$ & vice versa

Practical implications

1) Orbital speed is not constant unless circular orbit
2) Orbital speed is fastest at periapse
3) Orbital speed is slowest at apoapse

Law 3: The square of the period T of the orbit is proportional to the cube of the semi-major axis a

$$T^2 \propto a^3$$



$$\downarrow \text{const.}$$

e.g. given T_{inner} w/ a : $T_{inner}^2 = K a^3$

then if T_{outer} w/ $2a$: $T_{outer}^2 = K(2a)^3$

$$T_{outer}^2 = \frac{T_{inner}^2}{a^3} (2a)^3$$

$$T_{outer} = \sqrt{8}\, T_{inner} = 2\sqrt{2}\, T_{inner}$$