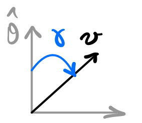
General formulas:

$\underline{h} = \underline{r} \times \dot{\underline{r}}$ $\quad h = \sqrt{\mu P} = r v_\theta = r^2 \dot{\theta}$ $\quad v_r = \frac{\mu}{h} e \sin\theta = \sqrt{\frac{\mu}{P}} e \sin\theta = \dot{r} = v \sin\gamma$

$\mathcal{E} = \frac{1}{2}v^2 - \frac{\mu}{r} = -\frac{\mu}{2a}$ $\quad P = h^2/\mu = a(1-e^2)$ $\quad T = \sqrt{\frac{4\pi^2 a^3}{\mu}}$ $\quad v_\theta = \frac{\mu}{h}(1+e\cos\theta) = \sqrt{\frac{\mu}{P}}(1+e\cos\theta) = r\dot{\theta} = v\cos\gamma$

$v_I = \sqrt{\frac{\mu}{r}}$ Circular $\quad v_{II} = \sqrt{2}\, v_I$ Escape $\quad v_{III} = \sqrt{-\frac{\mu}{a}} = v_\infty = \sqrt{C_3}$ Hyperbolic excess speed $\quad$ Rocket parameter



$\underline{e} = \frac{\dot{\underline{r}} \times \underline{h}}{\mu} - \frac{\underline{r}}{\|\underline{r}\|} = \frac{1}{\mu}\left[\left(v^2 - \frac{\mu}{r}\right)\underline{r} - r v_r \underline{v}\right]$

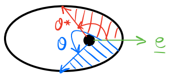
$r = \frac{P}{1+e\cos\theta}$ $\quad \tan\gamma = \frac{v_r}{v_\theta} = \frac{e\sin\theta}{1+e\cos\theta}$ if $v_\theta < 0$, then $\Delta\gamma = 2\pi - |\Delta\gamma|$

Elliptical: $0 < e < 1$ $\quad a > 0$ $\quad \mathcal{E} > 0$	Parabolic trajectories: $e = 1$ $\quad a \to \infty$ $\quad \mathcal{E} = 0$	Hyperbolic trajectories: $e > 1$ $\quad a < 0$ $\quad \mathcal{E} > 0$ $\quad P > 0$
$a = \frac{r_p + r_a}{2}$ $e = \frac{r_a - r_p}{r_a + r_p}$ $\quad b = a\sqrt{1-e^2}$ $\quad P = \frac{2 r_a r_p}{r_a + r_p}$	$\mathcal{E} = \frac{1}{2}v^2 - \frac{\mu}{r} = 0$ $\quad r_p > 0$ $\quad r_a < 0$ impossible since its magnitude of vector $a = \frac{P}{1-e^2} \to \infty$	$\theta_\infty = a\cos\left(-\frac{1}{e}\right)$ $\quad \delta = 2 a\sin\left(\frac{1}{e}\right)$ $\quad v_\infty = \sqrt{\mu/\bar{a}}$ $\bar{a} = \lvert a \rvert$ $\quad \bar{b} = \bar{a}\sqrt{e^2-1}$ $\quad b = -\bar{b}$ $\quad \Delta = \bar{b} = \bar{a}\sqrt{e^2-1}$

Time laws:

Ellipse: $\tan\frac{\theta}{2} = \sqrt{\frac{1+e}{1-e}} \tan\frac{E}{2}$ $\quad E - e\sin E = \sqrt{\frac{\mu}{a^3}}(t - t_P)$ $\quad M = \sqrt{\frac{\mu}{a^3}}(t - t_P)$ $\quad \dot{M} = \frac{h}{ab}$ $\quad \dot{E} = \frac{h}{br}$

if $\theta > \pi$



$\to \theta^* = 2\pi - \theta \to \Delta t_{a\to\theta} = T - \Delta t_{a \to \theta^*}$

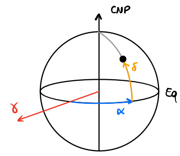
Hyperbola: $\tan\frac{\theta}{2} = \sqrt{\frac{1+e}{e-1}} \tanh\left(\frac{F}{2}\right)$ $\quad e\sinh F - F = \sqrt{\frac{\mu}{\bar{a}^3}}(t - t_P)$ $\quad \dot{E} = \frac{h}{br} i$ $\quad \dot{M} = -i \frac{h}{\bar{a}\bar{b}}$

Parabola: $D = \tan\left(\frac{\theta}{2}\right) = \tan(\gamma)$ $\quad \Delta t = t - t_P = \sqrt{\frac{P^3}{\mu}} \frac{1}{2}\left(D + \frac{D^3}{3}\right)$ $\quad \dot{E} = i\dot{E}$ $\quad \dot{M} = -i\dot{M}$

Right ascension and declination:

$\hat{r} = \cos\alpha\cos\delta\, \underline{i} + \sin\alpha\cos\delta\, \underline{j} + \sin\delta\, \underline{k} = \ell \underline{i} + m\underline{j} + n\underline{k}$ $\quad \begin{cases} \ell = x/r \\ m = y/r \\ n = z/r \end{cases}$

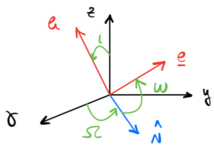
$\delta = a\sin\left(\frac{z}{r}\right)$ $\quad \alpha = \begin{cases} a\cos\left(\frac{x}{r}\frac{1}{\cos\delta}\right) & \text{if } \frac{y}{r} \geq 0 \\ 2\pi - a\cos\left(\frac{x}{r}\frac{1}{\cos\delta}\right) & \text{if } \frac{y}{r} < 0 \end{cases}$



Orbital Elements:

$\underline{r}, \underline{v} \to a, e, i, \Omega, \omega, \theta$

$a = \frac{1}{\left(\frac{2}{r} - \frac{v^2}{\mu}\right)}$ $\quad \underline{e} = \frac{1}{\mu}\left[\left(v^2 - \frac{\mu}{r}\right)\underline{r} - r v_r \underline{v}\right]$ $\quad \underline{h} = \underline{r} \times \underline{v}$ $\quad i = a\cos\left(\frac{\underline{z}\cdot\underline{h}}{h}\right)$ $\quad \hat{N} = \frac{\underline{z} \times \underline{h}}{\|\underline{z} \times \underline{h}\|}$



$\Omega = \begin{cases} a\cos(\hat{N}\cdot\hat{x}) & \text{if } \hat{N}\cdot\hat{y} > 0 \\ 2\pi - a\cos(\hat{N}\cdot\hat{x}) & \hat{N}\cdot\hat{y} < 0 \end{cases}$ $\quad \omega = \begin{cases} a\cos\left(\frac{\underline{e}\cdot\hat{N}}{e}\right) & \underline{e}\cdot\underline{k} > 0 \\ 2\pi - a\cos\left(\frac{\underline{e}\cdot\hat{N}}{e}\right) & \underline{e}\cdot\underline{k} < 0 \end{cases}$ $\quad \theta = \begin{cases} a\cos\left(\frac{\underline{r}\cdot\underline{e}}{r\cdot e}\right) & v_r > 0 \\ 2\pi - a\cos\left(\frac{\underline{r}\cdot\underline{e}}{r\cdot e}\right) & v_r < 0 \end{cases}$

$\begin{cases} \underline{v}_r = (\underline{v}\cdot\hat{r})\hat{r} \\ \underline{v}_\theta = \underline{v} - \underline{v}_r \end{cases}$

Transformations:

Programma calcolatrice

$R_{PF/ECEI} = \begin{bmatrix} \cos\omega\cos\Omega - \sin\omega\cos i \sin\Omega & \cos\omega\sin\Omega + \sin\omega\cos i\cos\Omega & \sin\omega\sin i \\ -\sin\omega\cos\Omega - \cos\omega\cos i\sin\Omega & -\sin\omega\sin\Omega + \cos\omega\cos i\cos\Omega & \cos\omega\sin i \\ \sin i\sin\Omega & -\sin i\cos\Omega & \cos i \end{bmatrix}$ $\quad R_{LVLH/PF} = \begin{bmatrix} \cos\theta & \sin\theta & 0 \\ -\sin\theta & \cos\theta & 0 \\ 0 & 0 & 1 \end{bmatrix}$

$\underline{V}_{LVLH} = \frac{\mu}{h}\begin{bmatrix} e\sin\theta \\ 1 + e\cos\theta \\ 0 \end{bmatrix}$ $\quad \underline{V}_{PF} = \frac{\mu}{h}\begin{bmatrix} -\sin\theta \\ e + \cos\theta \\ 0 \end{bmatrix}$

Coordinate systems:

Earth-centered ecliptic: β (celestial longitude) $\quad \ell$ (cel. latitude)

ECEI (CNP): α (right ascension) $0 \leq \alpha \leq 2\pi$ $\quad \delta$ (declination) $-\frac{\pi}{2} \leq \delta \leq \frac{\pi}{2}$

Topocentric horizon: Az (azimuth) $\quad h$ (elevation)

λ (longitude) $\quad \varphi$ (geographic lat.) or ϕ (geodesic lat.)

γ: Intersection between ecliptic and equatorial plane

Σ: Intersection between observer meridian and equatorial plane

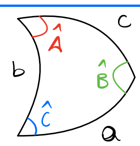
Spherical geometry:

$\cos a = \cos b\cos c + \sin b \sin c \cos\hat{A}$

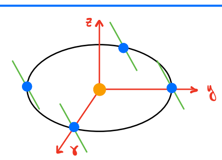
$\cos\hat{A} = -\cos\hat{B}\cos\hat{C} + \sin\hat{B}\sin\hat{C}\cos a$

$\frac{\sin a}{\sin\hat{A}} = \frac{\sin b}{\sin\hat{B}} = \frac{\sin c}{\sin\hat{C}}$

$\cot(a)\cdot\sin(b) = \cos(b)\cos(\hat{C}) + \sin(\hat{C})\cot(\hat{A})$



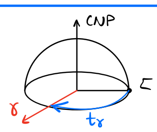
		spring ep.	summ sol.	aut. ep.	win. sol.
Sun	α	0	$\pi/2$	π	$3/2\,\pi$
	δ	0	$\Sigma = 23{,}4°$	0	$\Sigma = -23{,}4°$

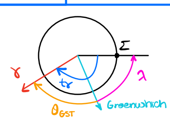


Measurements of time:

Local sidereal time: $LST = t_\gamma = \hat{\Sigma\gamma} = \theta_{LST} = \theta_{GST} + \lambda$ (Greenwhich sidereal time)

(Local standard time)





$1\ \text{year} = 365{,}25$ solar days $= 366{,}24$ sidereal days

Apparent local time: t: hour angle of real sun
$LAT = t + 12h$
$LAT = GAT + \lambda$

Mean local time: t_M: hour angle of mean sun
$LMT = t_M + 12h$
$LMT = GMT + \lambda$

$LAT = LMT + E$

$\frac{E - E_1}{GMT - GMT_1} = \frac{E_2 - E_1}{GMT_2 - GMT_1}$ $\quad GMT_1 \to 0$, $GMT_2 \to 24$, $GMT_1 \to 0$

Universal time: LMT wrt Greenwhich

Local civil time: $LCT = GMT + 1h\, n$ $\quad n = ceil\left(\text{sign}(\lambda)\frac{|\lambda| - 7{,}5°}{15°}\right)$

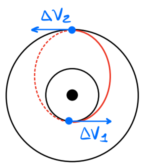
E is given @ 00:00

Impulsive maneuvers: $\Delta v = I_{sp}\cdot g_0 \ln\left(\frac{m_0}{m_f}\right)$ $\quad I_{sp} = \frac{T}{\boxed{\dot m_0 g_0}}$ @ sea level $\quad \Delta m = m_{propellant} = m_f - m_0 \quad \frac{m_p}{m_0} = 1 - \exp\left(-\frac{\Delta v}{I_{sp}\cdot g_0}\right)$

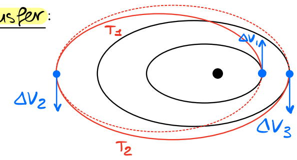
Hohmann: 2 circ, coplanar, cofocal orbits.

$\Delta t = TOF = \frac{T}{2}$ $\quad h = \sqrt{2\mu\frac{r_a\cdot r_p}{r_a + r_p}} = r\cdot v_\theta = r\cdot v\cdot\cos\gamma \quad \gamma = 0$ @ peri or apo

$v = \frac{h}{r}$ @ peri or apo $\quad \Delta V = |V_A| + |V_B|$

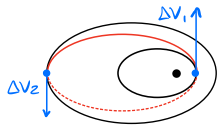


Bi-elliptic transfer:



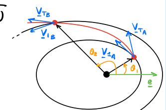
Generalised Hohmann: 2 elliptic, coplanar, cofocal orbits
From pericenter or apocenter

$\Delta t \rightarrow \frac{T}{2}$ of transfer orbit. Same as Hohmann



(secant) **Non-Hohmann transfer with common apse line**:
- transfer orbit is coaxial

transfer orbit: $\begin{cases} r_A = \frac{P_T}{1 + e_T\cos\theta_1} \\ r_B = \frac{P_T}{1 + e_T\cos\theta_2}\end{cases} \rightarrow P_T, e_T \rightarrow h_T = \sqrt{P\mu}$ $\quad \begin{cases} v_r = \frac{\mu}{h} e\sin\theta \\ v_\theta = \frac{\mu}{h}(1 + e\cos\theta)\end{cases}$



$\rightarrow \underline{v}_i = v_{r_i}\hat r + v_{\theta_i}\hat\theta \quad i = 1, \dots, 4$

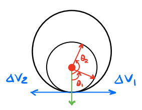
$\Delta \underline{V}_1 = \underline{v}_2 - \underline{v}_{T_B} \rightarrow \|\Delta \underline{V}\| = \|\Delta V_1\| + \|\Delta V_2\| = \|\underline{v}_{T_A} - \underline{v}_1\| + \|\underline{v}_2 - \underline{v}_{T_B}\| =$
$\Delta \underline{V}_2 = \underline{v}_{T_A} - \underline{v}_1$ $\qquad = \sqrt{V_1^2 + V_2^2 - 2V_1V_2\cos\Delta\gamma} + \sqrt{\dots}$

Flight path angle of $\Delta V_i \rightarrow \tan\Delta\phi_i = \frac{\Delta v_{r_i}}{\Delta v_{\theta_i}}$ $\quad i = 1, 2$

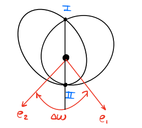
Phasing maneuver: For circular orbits: $T_{ph} = T_1\left(1 - \text{sign}(\Delta\theta)\frac{|\Delta\theta|}{360°\cdot n_{rev}}\right)$

$\Delta\theta = \theta_2 - \theta_1$ $\quad$ For elliptic orbits: $T_{ph} = \Delta t_{required}$

$a_T = \sqrt[3]{\frac{T_{ph}^2\,\mu}{4\pi^2}}$ $\quad \begin{cases} \text{if } \Delta\theta > 0 & \begin{cases} r_{a_T} = r_{P_1} \\ r_{P_T} = 2a_T - r_{a_T}\end{cases} \\ \text{if } \Delta\theta < 0 & \begin{cases} r_{P_T} = r_{P_1} \\ r_{a_T} = 2a_T - r_{P_T}\end{cases}\end{cases}$ $\quad \Delta V_{tot} = 2|\Delta V_1|$



(No shape change)



Apse line rotation: $\Delta\omega$ counter-clockwise > 0
$\rightarrow$ orbits have 2 intersections at most.

$\Delta\omega = \omega_2 - \omega_1 = \theta_1 - \theta_2$

$a\cos\theta_1 + b\sin\theta_1 = c$

$\begin{cases} a = h_2^2 e_1 - h_1^2 e_2\cos\eta \\ b = -h_1^2 e_2 \sin\eta \\ c = h_1^2 - h_2^2\end{cases}$ $\quad \begin{cases} \theta_1 = \phi \pm a\cos\left(\frac{c}{a}\cos\phi\right) \text{ with } \phi = \text{atan}\left(\frac{b}{a}\right) \\ \theta_2 = \theta_1 - \eta\end{cases} \rightarrow$ then $r_{I_①}$ and $r_{I_②}$

Case 1: Given $\eta = \Delta\omega$, $\boxed{e_1, e_2, h_1, h_2}$ or calculate this from data.

For Δv: $\begin{cases} v_{\theta_{I_1}} = \frac{h_1}{r_{I_1}} \\ v_{r_{I_1}} = \frac{\mu}{h_1} e_1\sin\theta_1 \\ \gamma_{I_1} = \text{atan}\left(\frac{v_{r_{I_1}}}{v_{\theta_{I_1}}}\right)\end{cases} \rightarrow \begin{cases} \underline{v}_1 = v_{r_{I_1}}\hat r + v_{\theta_{I_1}}\hat\theta \\ \text{Repeat for } \underline{v}_2 \\ \Delta \underline{v} = \underline{v}_2 - \underline{v}_1 \rightarrow \|\Delta \underline{v}\|\end{cases}$

Case 2: Given $\theta_{I_①}, \Delta \underline{v} \rightarrow$ find $\eta = \Delta\omega = \theta_1 - \theta_2$ and e_2, h_2

$\Delta \underline{v} = \underbrace{\Delta v_r}_{\Delta v \sin\gamma}\hat r + \underbrace{\Delta v_\theta}_{\Delta v\cos\gamma}\hat\theta \rightarrow \quad \tan\theta_{I_②} = \frac{\frac{v_{\theta_①}^2\cdot r_I}{\mu}(v_{\theta_1} + \Delta v_\theta)(v_{r_1} + \Delta v_r)}{(v_{\theta_1} + \Delta v_\theta)^2 e_1\cos\theta_1 + \Delta v_\theta(\Delta v_\theta + 2v_{\theta_1})}$

$\begin{cases} h_2 = h_1 + r_I\Delta v_\theta \\ e_2 = \frac{1}{\sin\theta_2}\frac{h_2}{\mu}(v_{r_1} + \Delta v_r) \\ \eta = \theta_1 - \theta_2\end{cases}$

Flight path angle of $\Delta \underline{v}$:
$\Delta\gamma = \text{atan}\left(\frac{\Delta v_r}{\Delta v_\theta}\right)$ if $v_\theta > 0$
$\Delta\gamma = \pi - \left|\text{atan}\left(\frac{\Delta v_r}{\Delta v_\theta}\right)\right|$ if $v_\theta < 0$

Case: No shape change $e_1, h_1, \omega_1 \rightarrow e_2 = e_1 \quad h_2 = h_1, \omega_2$

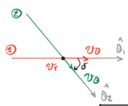
$\Delta\omega = \omega_1 - \omega_2 = \theta_2 - \theta_1 = -2\theta_1$
$\qquad (\theta_2 = -\theta_1)$

$\begin{cases} \theta_{I_①} = 180 - \frac{\Delta\omega}{2} \\ \theta_{I_②} = 180 + \frac{\Delta\omega}{2}\end{cases}$ $\quad \begin{cases} \theta_{I_①} = 360 - \frac{\Delta\omega}{2} \\ \theta_{I_②} = \frac{\Delta\omega}{2}\end{cases}$

$\Delta \underline{v}$ has to invert $v_r \rightarrow v_\theta$ is unchanged

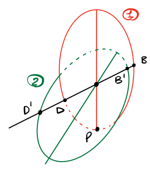
$\|\Delta \underline{v}\| = \Delta v = 2v_r = 2\cdot\sqrt{\frac{\mu}{P}}\, e\sin\left(\frac{\Delta\omega}{2}\right)$

Plane change: cofocal orbits, on 2 planes (if v_r changes, shape changes)



$\begin{cases} \underline{v}_1 = v_{r_1}\hat r + v_{\theta_1}\hat\theta \\ \underline{v}_2 = v_{r_2}\hat r + v_{\theta_2}\hat\theta\end{cases}$ $\quad \Delta \underline{v} = \underline{v}_2 - \underline{v}_1$

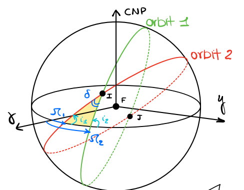
$\Delta v = \sqrt{(v_{r_2} - v_{r_1})^2 + v_{\theta_2}^2 + v_{\theta_1}^2 - 2v_{\theta_2}v_{\theta_1}\cos\delta}$
or
$\Delta v = \sqrt{v_1^2 + v_2^2 - 2v_1v_2(\cos\Delta\gamma - \cos\gamma_1\cos\gamma_2(1 - \cos\delta))}$

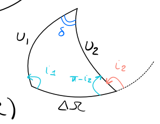


Particular cases:
1) No plane change $\rightarrow \delta = 0$
2) No shape change
$\begin{cases} v_{r_1} = v_{r_2} \\ \delta \neq 0\end{cases} \rightarrow \Delta v = 2v_\theta\sin\left(\frac{\delta}{2}\right)$
3) $\begin{cases} \Delta\Omega = \Omega_2 - \Omega_1 \\ U_1 = \omega_1 + \theta^* \\ U_2 = \omega_2 + \theta^*\end{cases}$ $\rightarrow \theta$ doesn't change
Find $\delta \rightarrow$ find Δv

$\cos\Delta\Omega = \cos U_1\cos U_2 + \sin U_1\sin U_2\cos\delta$

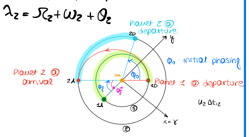
$\cos\delta = -\cos i_1\cos(\pi - i_2) + \sin(i_1)\sin(\pi - i_2)\cos(\Delta\Omega)$





Planet phasing: $\phi = \theta_2 - \theta_1 + (n_2 - n_1)\cdot t \quad T_{syn} = \frac{2\pi}{|n_2 - n_1|} \quad \Delta t_{12}^{Hohmann} = \frac{1}{2}\sqrt{\frac{4\pi^2}{\mu_{sun}}\left(\frac{R_1 + R_2}{2}\right)^3}$ $\quad \phi_{initial} = \pi - n_2\Delta t_{12}$ $\quad \phi_{final} = \pi - n_1\Delta t_{12}$

If elliptical $\begin{cases} u_1 = \omega_1 + \theta_1 \\ u_2 = \omega_2 + \theta_2\end{cases}$ if $i_2 \neq 0$ $\begin{cases} \lambda_1 = \Omega_1 + \omega_1 + \theta_1 \\ \lambda_2 = \Omega_2 + \omega_2 + \theta_2\end{cases}$



Patched conics method:

1) Interplanetary transfer (Hohmann) $\rightarrow \mu_{sun}$

$\Delta V_1 \rightarrow$ find $\underline{v}_\infty^+$ at planet 1 $\quad \underline{V}_{SC} = \underline{v}_\infty^+ + \underline{V}_{planet\,1}$
$\Delta V_2 \rightarrow$ find $\underline{v}_\infty^-$ at planet 2 $\quad \underline{V}_{SC} = \underline{v}_\infty^- + \underline{V}_{planet\,2}$

In case of Hohmann: $\underline{v}_\infty^+ \parallel \underline{v}_1 \parallel \underline{v}_{S/C}$

ΔV opposite to $\underline{e}$

Don't align pericenter with frames.

2) Planet SOI: $r_{SOI} = R_{sun\text{-}planet}\left(\frac{m_p}{m_s}\right)^{2/5}$

$V_{SC} = \underline{v}_{rel} + \underline{V}_{planet}$
$\hookrightarrow v_\infty$: hyperbolic excess speed

$\mathcal{E}_\infty = \mathcal{E}_p = \frac{1}{2}v^2 - \frac{\mu}{r} = -\frac{\mu}{2a} \rightarrow a_{hyp} \rightarrow v_{p,hyp}$

$v_\infty = v_{r_\infty} = \frac{\mu}{h}\sqrt{e^2 - 1} \rightarrow$ find e without r_p

$e_{hyp} = \frac{r_p v_\infty^2}{\mu_p} + 1 = \sqrt{\left(\frac{v_\infty h_{hyp}}{\mu}\right)^2 + 1}$

$a_{hyp} = \frac{p_{hyp}}{1 - e_{hyp}^2}$

$h_{hyp} = r_p\sqrt{v_\infty^2 + \frac{2\mu_p}{r_p}} = \Delta\cdot v_\infty$

$v_{p,hyp} = \frac{h_{hyp}}{r_p}$

$\delta = 2a\sin\left(\frac{1}{1 + \frac{r_p v_\infty^2}{\mu}}\right) = 2\,\text{atan}\left(-\frac{a_{hyp}}{\Delta}\right)$

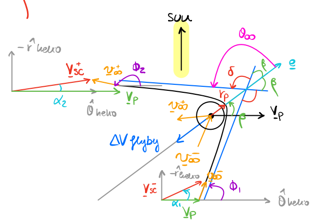
$\beta = 90° - \frac{\delta}{2} = a\cos\left(\frac{1}{e_{hyp}}\right)$

$\Delta = b = a\sqrt{e^2 - 1} = r_p\cdot\sqrt{1 + \frac{2\mu_p}{r_p v_\infty^2}}$

$\underline{r}_{maneuver} = r_p\begin{bmatrix}\cos\beta \\ \sin\beta \\ 0\end{bmatrix}$

$\Delta \underline{v} = \underline{V}_{SC}^+ - \underline{V}_{SC}^- = \underline{v}_\infty^+ - \underline{v}_\infty^-$

$\Delta V = 2v_\infty\sin\left(\frac{\delta}{2}\right)$

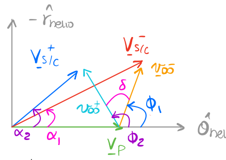


counter-clockwise rotation:

$\begin{bmatrix}x' \\ y' \\ z'\end{bmatrix} = \begin{bmatrix}\cos\delta & -\sin\delta & 0 \\ \sin\delta & \cos\delta & 0 \\ 0 & 0 & 1\end{bmatrix}\begin{bmatrix}x \\ y \\ z\end{bmatrix}$

$\underline{e} = \dots \rightarrow$ car2kep $\begin{pmatrix} v_r = (\underline{v}\cdot\hat r)\hat r \\ v_\theta = (\underline{v}\cdot\hat\theta)\hat\theta\end{pmatrix}$

Flight path of $\begin{cases} v_\infty^- & \phi_1 = \text{atan}\left(\frac{[v_\infty^-]_s}{[v_\infty^-]_v}\right) = \text{atan}\left(\frac{V_1^{SC}\sin\alpha_1}{V_1^{SC}\cos\alpha_1 - V_p}\right) \\ v_\infty^+ & \phi_2 = \phi_1 + \delta\end{cases}$



- Frame has to be seen
- $v_\infty^+ = v_\infty^-$
- $\Delta \underline{V}_{fly\text{-}by} = \underline{V}_{SC}^+ - \underline{V}_{SC}^- = \underline{v}_\infty^+ - \underline{v}_\infty^-$