Question 1a

$$t\_1 := \frac{(V\_0 - V\_E)}{a}$$

$$t\_1 := \frac{V\_0 - V\_E}{a} \quad (1)$$

> $V\_pc(t) := m \cdot t + u\_pc0$

$$V\_pc := t \mapsto m \cdot t + u\_pc0 \quad (2)$$

$$V\_b(t) := V\_b0 + V\_pc(t)$$

$$V\_b := t \mapsto V\_b0 + V\_pc(t) \quad (3)$$

$$t\_2(t) := \frac{V\_b(t)}{a} + t - \frac{V\_0}{a}$$

$$t\_2 := t \mapsto \frac{V\_b(t)}{a} + t - \frac{V\_0}{a} \quad (4)$$

$$x(t) := \frac{m}{2} \cdot t^2 + u\_pc0 \cdot t + x\_0$$

$$x := t \mapsto \frac{1}{2} \cdot m \cdot t^2 + u\_pc0 \cdot t + x\_0 \quad (5)$$

$$V\_0\_func := t\_f \rightarrow solve\Big(x(t\_f) = (((V\_0 - V\_E)/2) * t\_1 + V\_E * t\_1 + V\_0 * (t\_2(t\_f) - t\_1)) - \Big((a/2) * t\_f\verb|^|2 - (a * t\_2(t\_f) + V\_0) * t\_f + t\_2(t\_f) \cdot \left(\frac{a}{2} \cdot t\_2(t\_f) + V\_0\right)\Big), V\_0\Big)$$

$$V\_0\_func := t\_f \mapsto solve\left(x(t\_f) = \left(\frac{V\_0}{2} - \frac{V\_E}{2}\right) \cdot t\_1 + V\_E \cdot t\_1 + V\_0 \cdot (t\_2(t\_f) - t\_1) - \frac{a \cdot t\_f^2}{2} + (a \cdot t\_2(t\_f) + V\_0) \cdot t\_f - t\_2(t\_f) \cdot \left(\frac{a \cdot t\_2(t\_f)}{2} + V\_0\right), V\_0\right) \quad (6)$$

> $V\_0\_func(t\_f)[2]$

$$\frac{t\_f\ a}{2} + \frac{m\ t\_f}{2} + \frac{V\_E}{2} + \frac{V\_b0}{2} + \frac{u\_pc0}{2} - \frac{1}{2}\Big(a^2\ t\_f^2 - m^2\ t\_f^2 + 2\ V\_E\ a\ t\_f + 2\ V\_E\ m\ t\_f + 2\ V\_b0\ a\ t\_f - 2\ V\_b0\ m\ t\_f - 2\ u\_pc0\ t\_f\ a - 2\ m\ t\_f\ u\_pc0 - V\_E^2 + 2\ V\_E\ V\_b0 + 2\ V\_E\ u\_pc0 - V\_b0^2 - 2\ V\_b0\ u\_pc0 - 4\ x\_0\ a - u\_pc0^2\Big)^{1/2} \quad (7)$$

> $V\_0\_val\_out(t\_f) := piecewise(V\_0\_func(t\_f)[2] > 42100, V\_0\_func(t\_f)[2], V\_0\_func(t\_f)[2] \leq 42100, 42100)$

$$V\_0\_val\_out := t\_f \mapsto \begin{cases} V\_0\_func(t\_f)_2 & 42100 < V\_0\_func(t\_f)_2 \\ 42100 & V\_0\_func(t\_f)_2 \leq 42100 \end{cases} \quad (8)$$

> $V\_0\_val\_back(t\_f) := piecewise(V\_0\_func(t\_f)[2] > 42100, V\_0\_func(t\_f)[2], V\_0\_func(t\_f)[2] \leq 65800, 65800)$

$$V\_0\_val\_back := t\_f \mapsto \begin{cases} V\_0\_func(t\_f)_2 & 42100 < V\_0\_func(t\_f)_2 \\ 65800 & V\_0\_func(t\_f)_2 \leq 65800 \end{cases} \quad (9)$$

$V\_0\_val(1e5 \cdot yr\_sec)$

$$V\_0\_val(100000.\ yr\_sec) \tag{10}$$

> $V\_0\_func(t\_f)[2]$

$$\frac{t\_f\ a}{2} + \frac{m\ t\_f}{2} + \frac{V\_E}{2} + \frac{V\_b0}{2} + \frac{u\_pc0}{2} - \frac{1}{2}\big(a^2\ t\_f^2 - m^2\ t\_f^2 + 2\ V\_E\ a\ t\_f + 2\ V\_E\ m\ t\_f + 2\ V\_b0\ a\ t\_f - 2\ V\_b0\ m\ t\_f - 2\ u\_pc0\ t\_f\ a - 2\ m\ t\_f\ u\_pc0 - V\_E^2 + 2\ V\_E\ V\_b0 + 2\ V\_E\ u\_pc0 - V\_b0^2 - 2\ V\_b0\ u\_pc0 - 4\ x\_0\ a - u\_pc0^2\big)^{1/2} \tag{11}$$

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Rocket Equations

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$$\Delta v(t\_f) := |V\_0\_val\_out(t\_f) - V\_E| + |-V\_0\_val\_out(t\_f) + V\_b(t\_f)| + |V\_pc(t\_f) - V\_b0 + V\_0\_val\_back(t\_f)| + |-V\_E + V\_0\_val\_back(t\_f)|$$

$$\Delta v := t\_f \mapsto |V\_0\_val\_out(t\_f) - V\_E| + |-V\_0\_val\_out(t\_f) + V\_b(t\_f)| + |V\_pc(t\_f) - V\_b0 + V\_0\_val\_back(t\_f)| + |-V\_E + V\_0\_val\_back(t\_f)| \tag{12}$$

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> $\Delta v(t\_f)$

$$\Bigg| - \Bigg(\Bigg\{ \frac{t\_f\ a}{2} + \frac{m\ t\_f}{2} + \frac{V\_E}{2} + \frac{V\_b0}{2} + \frac{u\_pc0}{2} - \frac{\sqrt{a^2\ t\_f^2 - m^2\ t\_f^2 + 2\ V\_E\ a\ t\_f + 2\ V\_E\ m\ t\_f + 2}}{}$$

$$\Bigg) + V\_E \Bigg| + \Bigg| - \Bigg(\Bigg\{ \frac{t\_f\ a}{2} + \frac{m\ t\_f}{2} + \frac{V\_E}{2} + \frac{V\_b0}{2} + \frac{u\_pc0}{2} - \frac{\sqrt{a^2\ t\_f^2 - m^2\ t\_f^2 + 2\ V\_E\ a\ t\_f + 2}}{}$$

$$\Bigg) + m\ t\_f + V\_b0 + u\_pc0 \Bigg| + \Bigg| -m\ t\_f - u\_pc0 + V\_b0 - \Bigg(\Bigg\{ \frac{t\_f\ a}{2} + \frac{m\ t\_f}{2} + \frac{V\_E}{2} + \frac{V\_b0}{2} + \frac{u\_pc}{2}$$

$$\Bigg)\Bigg| + \Bigg| V\_E - \Bigg(\Bigg\{ \frac{t\_f\ a}{2} + \frac{m\ t\_f}{2} + \frac{V\_E}{2} + \frac{V\_b0}{2} + \frac{u\_pc0}{2} - \frac{\sqrt{a^2\ t\_f^2 - m^2\ t\_f^2 + 2\ V\_E\ a\ t\_f + 2\ V\_}}{}$$

$$\Bigg)\Bigg|$$

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Question 1b

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> $V\_max(t\_f, m\_mir\_m\_tot) := \mathrm{sqrt}\left(\left(\left(m\_mir\_m\_tot * \frac{(1+R)}{2} * L\_star\right) / (2 * \mathrm{Pi} * c * \mathrm{rho})\right) * (1 / r\_0)\right) + V\_b(t\_f);$

$$V\_max := (t\_f, m\_mir\_m\_tot) \mapsto \sqrt{\frac{m\_mir\_m\_tot \cdot \left(\frac{1}{2} + \frac{R}{2}\right) \cdot L\_star}{2 \cdot \pi \cdot c \cdot \rho \cdot r\_0}} + V\_b(t\_f) \tag{14}$$

> $V\_max(t\_f, m\_mir\_m\_tot)$

$$\frac{\sqrt{2}\,\sqrt{\frac{m\_mir\_m\_tot\,\left(\frac{1}{2} + \frac{R}{2}\right)\,L\_star}{\pi\, c\, \rho\, r\_0}}}{2} + m\, t\_f + V\_b0 + u\_pc0 \tag{15}$$

$final\_time\_sail(m\_mir\_m\_tot) := solve\left(t\_f = \frac{x(t\_f)}{V\_max(t\_f, m\_mir\_m\_tot)}, t\_f\right)[1]$

$$final\_time\_sail := m\_mir\_m\_tot \mapsto solve\left(t\_f = \frac{x(t\_f)}{V\_max(t\_f, m\_mir\_m\_tot)}, t\_f\right)_1 \tag{16}$$

> $final\_time\_sail(mr)$

$$\frac{1}{2\, m}\left(-\sqrt{\frac{mr\,(1+R)\,L\_star}{\pi\, c\, \rho\, r\_0}} - 2\, V\_b0 + \left(\frac{1}{\pi\, c\, \rho\, r\_0}\left(4\sqrt{\frac{mr\,(1+R)\,L\_star}{\pi\, c\, \rho\, r\_0}}\, V\_b0\, \pi\, c\, \rho\, r\_0 + 4\, V\_b0^2\, \pi\, c\, \rho\, r\_0 + 8\, m\, x\_0\, \pi\, c\, \rho\, r\_0 + mr\, L\_star\, R + mr\, L\_star\right)\right)^{1/2}\right) \tag{17}$$

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