P – P

$$T_0 = \frac{\dot{R}_i}{a} \qquad T_1 = T_2 = T_3 = T_0 + \sqrt{\frac{R_\phi - R_4}{a}} \qquad T_4 = T_3 + \sqrt{\frac{R_\phi - R_4}{a}}$$

$$R_\phi = R_i + \frac{\dot{R}_i^2}{2a} \qquad R_1 = R_2 = R_3 = \frac{R_\phi + R_4}{2}$$

P – E – P

$$T_0 = \frac{\dot{R}_i}{a} \qquad T_1 = T_2 = T_0 + \Delta T_{1_{PE}}$$

$$R_0 = R_i + \frac{\dot{R}_i^2}{2a} \qquad R_1 = R_2 = R_\phi - \frac{a \Delta T_{1_{PE}}^2}{2}$$

$$\Delta T_4 = T_c - \sqrt{T_c^2 - \frac{2(R_4 - R_5)}{a}}$$

$$\Delta T_3 = -T_c \ln\left\{\frac{R_4 - R_5 + \frac{a \Delta T_4^2}{2}}{R_2 - R_5}\right\}$$

$$R_3 = R_4 + \frac{a \Delta T_4^2}{2}$$

NOTE: TOTAL TIME FOR PEP IF $\dot{R}_i = \phi$

$$T_{PEP} = \Delta T_{1_{PE}} + \Delta T_3 + \Delta T_4$$

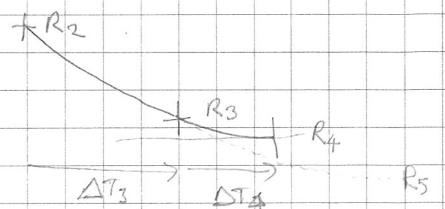
$$= \sqrt{T_c^2 + \frac{2(R_\phi - R_5)}{a}} \cancel{- T_c}$$

$$- T_c \ln\left\{\frac{R_4 - R_5 + \frac{a}{2}\left(T_c - \sqrt{T_c^2 - \frac{2(R_4 - R_5)}{a}}\right)}{R_2 - R_5}\right\}$$

$$\cancel{+ T_c} - \sqrt{T_c^2 - \frac{2(R_4 - R_5)}{a}}$$

$$T_{PEP} = \left(T_c^2 + \frac{2(R_\phi - R_5)}{a}\right)^{1/2} - \left(T_c^2 - \frac{2(R_4 - R_5)}{a}\right)^{1/2} - T_c \ln\left\{\frac{R_4 - R_5 + \frac{aT_c}{2} - \left(\frac{(aT_c)^2}{4} - \frac{a(R_4 - R_5)}{2}\right)^{1/2}}{R_2 - R_5}\right\}$$

Derivation of ΔT_4:



exp: $R = (R_2 - R_5) e^{-\frac{t}{T_c}} + R_5$

$$\dot{R} = \frac{-R + R_5}{T_c}$$

par: $R = R_4 + \frac{1}{2} a t^2$

$$\dot{R} = -at$$

So at join: $-R + R_5 = -a T_c \Delta T_4$

$$-R_4 - \frac{1}{2} a \Delta T_4^2 + R_5 = -a T_c \Delta T_4$$

$$\therefore \quad \left(\frac{a}{2}\right) \Delta T_4^2 - a T_c \, \Delta T_4 + (R_4 - R_5) = \phi$$

$$\Delta T_4 = \frac{a T_c \pm \sqrt{a^2 T_c^2 - 4 \frac{a}{2} (R_4 - R_5)}}{2\left(\frac{a}{2}\right)}$$

Take minimum root:

$$\therefore \quad \Delta T_4 = T_c - \sqrt{T_c^2 - \frac{2(R_4 - R_5)}{a}}$$

root is only real if $T_c^2 > \frac{2}{a}(R_4 - R_5)$

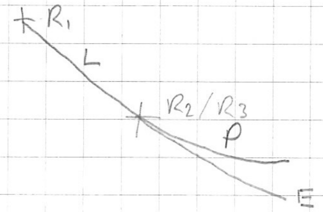
So $R_5 \geq R_4 - \frac{a T_c^2}{2}$

Derivation of ΔT_3:

At join: $R_3 = (R_2 - R_5) e^{-\frac{\Delta T_3}{T_c}} + R_5 = R_4 + \frac{1}{2} a \Delta T_4^2$

$$\therefore \quad \Delta T_3 = -T_c . \ln \left\{ \frac{R_4 - R_5 + \frac{a \Delta T_4^2}{2}}{R_2 - R_5} \right\}$$

P-L-P or P-L-E-P



$\dot{R} = -L$ for Linear descent.

exp: $\dot{R} = -L = \frac{-R_2 + R_5}{T_c} \Rightarrow R_2 = R_5 + L T_c$

Par: $R_3 = R_4 + \frac{L^2}{2a}$

P-L-P if $R_3 > R_2$ else P-L-E-P

if $R_4 + \frac{L^2}{2a} > R_5 + L T_c$

P-L-P: $R_2 = R_3 = R_4 + L^2/2a$

$$\Delta T_2 = \frac{R_1 - R_2}{L}$$

$$\Delta T_4 = \frac{L}{a}$$

P-L-E-P $\quad R_2 = R_5 + L T_c$

ΔT_4, ΔT_3, R_3 as for P-E-P.