A4) $\varphi_1(z_3, z_1) = \frac{z_3^2}{(\delta - z_1)^2}$ $\approx$ $\varphi_1(z_3^e, z_1^e) + \frac{\partial \varphi_1}{\partial z_3}\Big|_{z_3^e, z_1^e} (z_3 - z_3^e) + \frac{\partial \varphi_1}{\partial z_1}\Big|_{z_3^e, z_1^e} (z_1 - z_1^e)$ Taylor's

$$\frac{\partial \varphi_1}{\partial z_3} = \frac{2 z_3}{(\delta - z_1)^2} = a_1 \text{ (eval at eq)} \qquad \frac{\partial \varphi_1}{\partial z_1} = z_3^2 (\delta - z_1)^{-2} = (-2) z_3^2 (\delta - z_1)^{-3} (-1) = \frac{2 z_3^2}{(\delta - z_1)^3}$$

$= a_2$ (eval at eq)

$$\therefore \frac{z_3^2}{(\delta - z_1)^2} - \frac{(z_3^e)^2}{(\delta - z_1^e)^2} \approx a_1 (z_3 - z_3^e) + a_2 (z_1 - z_1^e)$$

$$\varphi_2(V, z_3, z_1) = \frac{V - z_3 R}{L_0 + L_1 e^{\alpha z_1 - \alpha \delta}} \approx \varphi_2(V^e, z_3^e, z_1^e) + \frac{\partial \varphi_2}{\partial V}\Big|_{V^e, z_3^e, z_1^e} (V - V^e) + \ldots$$

$$\frac{\partial \varphi_2}{\partial V} = \frac{1}{L_0 + L_1 e^{\alpha z_1 - \alpha \delta}} \frac{\partial}{\partial V}(V - z_3 R) = \frac{1}{L_0 + L_1 e^{\alpha(z_1 - \delta)}} = a_3 \text{ (evaled at eq)}$$

$$\frac{\partial \varphi_2}{\partial z_3} = \frac{1}{L_0 + L_1 e^{\alpha(z_1 - \delta)}} \frac{\partial}{\partial z_3}(V - z_3 R) = \frac{-R}{L_0 + L_1 e^{\alpha(z_1 - \delta)}}$$

$$\frac{\partial \varphi_2}{\partial z_1} = (V - z_3 R) \cdot \frac{\partial}{\partial z_1}\left((L_0 + L_1 e^{\alpha z_1 - \alpha \delta})^{-1} \right)$$

$$= (V - z_3 R) \left[(-1)(L_0 + L_1 e^{\alpha z_1 - \alpha \delta})^{-2} (\alpha L_1 e^{\alpha(z_1 - \delta)}) \right]$$

$$= \frac{-\alpha L_1 e^{\alpha(z_1 - \delta)} (V - z_3 R)}{(L_0 + L_1 e^{\alpha(z_1 - \delta)})^2} \Rightarrow a_4 \text{ (evaled at eq) +ve constant}$$

$$a_4 = \frac{\alpha L_1 e^{\alpha(z_1 - \delta)} (V - z_3 R)}{(L_0 + L_1 e^{\alpha(z_1 - \delta)})^2}$$

$$\therefore \frac{V - z_3 R}{L_0 + L_1 e^{\alpha(z_1 - \delta)}} - \frac{V^e - z_3^e R}{L_0 + L_1 e^{\alpha(z_1^e - \delta)}} \approx a_3 \left[(V - V^e) - R(z_3 - z_3^e) \right] - a_4 (z_1 - z_1^e)$$

$$\bar{z}_1 = z_1 - z_1^e \qquad \bar{z}_2 = z_2 \qquad \bar{z}_3 = z_3 - z_3^e \qquad \bar{V} = V - V^e$$

$$\therefore \quad \boxed{\begin{aligned} \dot{\bar{z}}_1 &= \bar{z}_2 \\ \dot{\bar{z}}_2 &= \frac{5m}{7}\left[c\left(a_1 \bar{z}_3 + a_2 \bar{z}_1\right) - k\bar{z}_1 - b\bar{z}_2\right] \\ \dot{\bar{z}}_3 &= a_3\left[\bar{V} - R\bar{z}_3\right] - a_4\bar{z}_1 \end{aligned}}$$

$$a_1 = \frac{2 z_3^e}{(\delta - z_1^e)^2} \qquad a_2 = \frac{2(z_3^e)^2}{(\delta - z_1)^3}$$

$$a_3 = \frac{1}{L_0 + L_1 e^{\alpha(z_1^e - \delta)}} \qquad a_4 = \frac{\alpha L_1 e^{\alpha(z_1^e - \delta)}(V^e - z_3^e R)}{L_0 + L_1 e^{\alpha(z_1^e - \delta)}}$$