A3)
$$Z = \begin{bmatrix} x \\ \dot{x} \end{bmatrix} = \begin{bmatrix} Z_1 \\ \dot{z} \end{bmatrix}$$
 $Z = \begin{bmatrix} \frac{5m}{7} (mgSin\phi + \frac{cZ_3}{(8-Z_1)^2} - k(z_1 - \delta) - bZ_2) \\ I \end{bmatrix} = \begin{bmatrix} Z_1 \\ Z_3 \end{bmatrix}$ $I = \begin{bmatrix} \frac{5m}{7} (mgSin\phi + \frac{cZ_3}{(8-Z_1)^2} - k(z_1 - \delta) - bZ_2) \\ I \end{bmatrix}$

$$\ddot{Z}_{1} = Z_{2}$$
 $\ddot{Z}_{2} = \frac{5m}{7} \left(\text{mgSin} \Phi + \frac{cZ_{3}}{(\delta - Z_{1})^{2}} - k(Z_{1} - \delta) - bZ_{2} \right)$
 $\ddot{Z}_{3} = \frac{1}{k_{0} + k_{1}^{-2} (\delta^{2} Z_{1})} \left(V - Z_{3} R \right)$

Characterising the equilibrium point: f(zeve) = 0

$$0 = \frac{z^{e}}{7} \left(\frac{z^{e}}{mg \sin \phi} + \frac{c(z^{e})^{2}}{(\delta - z^{e})^{2}} - k(z^{e} - \delta) - 0 \right)$$
 makes sense vel of ball=0

$$l_{o} + l_{e} = \frac{c(z^{e})^{2}}{k(\delta - z^{e})}$$
 as $\frac{z^{e}}{(\delta - z^{e})^{2}} = \frac{c(z^{e})^{2}}{k(\delta - z^{e})^{2}} - k(z^{e} - \delta) - 0$ makes sense vel of ball=0

Subtracting:

$$\frac{\ddot{z}_{1} = Z_{2} - Z_{2}^{e}}{\ddot{z}_{2}} = \frac{2}{7} (\text{mySan}\phi + \frac{c(Z_{3}^{e})^{2}}{(\delta - Z_{1}^{e})^{2}} - h(Z_{1} - \delta) - bZ_{2}) - \frac{5}{7} (\text{mySan}\phi + \frac{c(Z_{3}^{e})^{2}}{(\delta - Z_{1}^{e})^{2}} - h(Z_{1}^{e} - \delta))$$

$$\dot{Z}_{3} = \frac{V - Z_{3}R}{L_{0} + L_{1}e} - \frac{V^{e} - Z_{3}^{e}R}{L_{0} + L_{1}e}$$

$$\vec{Z}_2 = \frac{5m8 \ln \phi + 5mc}{7} \left[\frac{Z_3^2}{6 - Z_1 \right]^2 - \frac{5mkZ_1 + 5mkc}{7} - \frac{5mbZ_2}{7} \right]$$

$$-\frac{5mmgSon\phi}{7} - \frac{5mc}{7} \left[\frac{(Z_3^e)^2}{(\delta - Z_1^e)^2} \right] + \frac{5mkZ_1^e}{7} - \frac{5mkZ_2^e}{7}$$

$$\frac{1}{7} = \frac{5m}{7} \left[c \left(\frac{Z_3^2}{(S-Z_1)^2} - \frac{(Z_3^e)^2}{(S-Z_1^e)^2} \right) - k \left(Z_1 - Z_1^e \right) - b Z_2 \right] + \frac{1}{7} \left[c \left(\frac{Z_3^2}{(S-Z_1^e)^2} - \frac{(Z_3^e)^2}{(S-Z_1^e)^2} \right) - k \left(\frac{Z_1 - Z_1^e}{(S-Z_1^e)^2} - \frac{(Z_3^e)^2}{(S-Z_1^e)^2} \right) \right] + \frac{1}{7} \left[c \left(\frac{Z_3^2}{(S-Z_1^e)^2} - \frac{(Z_3^e)^2}{(S-Z_1^e)^2} \right) - k \left(\frac{Z_1 - Z_1^e}{(S-Z_1^e)^2} - \frac{(Z_3^e)^2}{(S-Z_1^e)^2} \right) \right] + \frac{1}{7} \left[c \left(\frac{Z_3^2}{(S-Z_1^e)^2} - \frac{(Z_3^e)^2}{(S-Z_1^e)^2} - \frac{(Z_3^e)^2}{(S-Z_1^e)^2} \right) \right] + \frac{1}{7} \left[c \left(\frac{Z_3^e}{(S-Z_1^e)^2} - \frac{(Z_3^e)^2}{(S-Z_1^e)^2} - \frac{(Z_3^e)^2}{(S-Z_1^e)^2} \right) \right] + \frac{1}{7} \left[c \left(\frac{Z_3^e}{(S-Z_1^e)^2} - \frac{(Z_3^e)^2}{(S-Z_1^e)^2} - \frac{(Z_3^e)^2}{(S-Z_1^e)^2} \right) \right] + \frac{1}{7} \left[c \left(\frac{Z_3^e}{(S-Z_1^e)^2} - \frac{(Z_3^e)^2}{(S-Z_1^e)^2} - \frac{(Z_3^e)^2}{(S-Z_1^e)^2} \right) \right] + \frac{1}{7} \left[c \left(\frac{Z_3^e}{(S-Z_1^e)^2} - \frac{(Z_3^e)^2}{(S-Z_1^e)^2} - \frac{(Z_3^e)^2}{(S-Z_1^e)^2} \right) \right] + \frac{1}{7} \left[c \left(\frac{Z_3^e}{(S-Z_1^e)^2} - \frac{(Z_3^e)^2}{(S-Z_1^e)^2} - \frac{(Z_3^e)^2}{(S-Z_1^e)^2} - \frac{(Z_3^e)^2}{(S-Z_1^e)^2} \right) \right] + \frac{1}{7} \left[c \left(\frac{Z_3^e}{(S-Z_1^e)^2} - \frac{(Z_3^e)^2}{(S-Z_1^e)^2} - \frac{(Z_3^e)^2}{(S-Z_1^e)^2} - \frac{(Z_3^e)^2}{(S-Z_1^e)^2} \right) \right] + \frac{1}{7} \left[c \left(\frac{Z_3^e}{(S-Z_1^e)^2} - \frac{(Z_3^e)^2}{(S-Z_1^e)^2} - \frac{(Z_3^e)^2}{(S-Z_1^e)^2} - \frac{(Z_3^e)^2}{(S-Z_1^e)^2} \right) \right] + \frac{1}{7} \left[c \left(\frac{Z_3^e}{(S-Z_1^e)^2} - \frac{(Z_3^e)^2}{(S-Z_1^e)^2} - \frac{(Z_3^e)^2}{(S-Z_1^e)^2} - \frac{(Z_3^e)^2}{(S-Z_1^e)^2} - \frac{(Z_3^e)^2}{(S-Z_1^e)^2} \right] + \frac{1}{7} \left[c \left(\frac{Z_3^e}{(S-Z_1^e)^2} - \frac{(Z_3^e)^2}{(S-Z_1^e)^2} - \frac{(Z_3^e)^2}{(S-Z_1^e)^2} - \frac{(Z_3^e)^2}{(S-Z_1^e)^2} \right] + \frac{1}{7} \left[c \left(\frac{Z_3^e}{(S-Z_1^e)^2} - \frac{(Z_3^e)^2}{(S-Z_1^e)^2} - \frac{(Z_3^e)^2}{(S-Z_1^e)^2} - \frac{(Z_3^e)^2}{(S-Z_1^e)^2} \right] \right] + \frac{1}{7} \left[c \left(\frac{Z_3^e}{(S-Z_1^e)^2} - \frac{(Z_3^e)^2}{(S-Z_1^e)^2} - \frac{(Z_3^e)^2}{(S-Z_1^e)^2} - \frac{(Z_3^e)^2}{(S-Z_1^e)^2} \right] \right] + \frac{1}{7} \left[c \left(\frac{Z_3^e}{(S-Z_1^e)^2} - \frac{(Z_3^e)^2}{(S-Z_1^e)^2} - \frac{(Z_3^e)^2}{(S-Z_1^e)^2} \right] \right]$$

$$\frac{\ddot{Z}_{3} = V - Z_{3}R}{\lambda_{0} + \lambda_{1} e^{\kappa(Z_{1} - \delta)}} \frac{V^{e} - Z_{3}R}{\lambda_{0} + \lambda_{1} e^{\kappa(Z_{1}^{e} - \delta)}}$$

$$\frac{\dot{Z}_{2} = 5m}{7} \left[c \left(\frac{Z_{3}^{2}}{(\delta - Z_{1})^{2}} - \frac{(Z_{3}^{e})^{2}}{(\delta - Z_{3}^{e})^{2}} \right) - k(Z_{1} - Z_{1}^{e}) - bZ_{2} \right]$$

$$Z_3 = \frac{V - Z_3 R}{\sqrt{c + k_1 e^{\alpha(Z_1 - \delta)}}}$$

$$\frac{V^2 - Z_3^2 R}{\sqrt{c + k_1 e^{\alpha(Z_1^2 - \delta)}}}$$