* Correction

A3) $z = \begin{bmatrix} x \\ \dot{x} \\ I \end{bmatrix} = \begin{bmatrix} z_1 \\ z_2 \\ z_3 \end{bmatrix}$ $\qquad \dot{z} = \begin{bmatrix} z_2 \\ \frac{5m}{7m}\left(mg\sin\phi + \frac{cz_3^2}{(\delta - z_1)^2} - k(z_1 - d) - bz_2\right) \\ L_0 + L_1 e^{-\alpha(\delta - z_1)} (V - z_3 R) \end{bmatrix}$

$$\dot{z}_1 = z_2$$
$$\dot{z}_2 = \frac{5m}{7m}\left(mg\sin\phi + \frac{cz_3^2}{(\delta - z_1)^2} - k(z_1 - d) - bz_2\right)$$
$$\dot{z}_3 = \frac{1}{L_0 + L_1 e^{-\alpha(\delta - z_1)}} (V - z_3 R)$$

Characterising the equilibrium point : $f(z^e, v^e) = 0$

as $z_2^e = 0$

$$0 = z_2^e$$
$$0 = \frac{5m}{7m}\left(mg\sin\phi + \frac{c(z_3^e)^2}{(\delta - z_1^e)^2} - k(z_1^e - d) - 0\right)$$

makes sense as ~~speed~~ vel of ball=0

$$0 = \frac{1}{L_0 + L_1 e^{-\alpha(\delta - z_1^e)}} (v^e - z_3^e R)$$

This

A4) → Subtracting:

$$\dot{z}_1 = z_2 - z_2^e$$
$$\dot{z}_2 = \frac{5m}{7m}\left(mg\sin\phi + \frac{cz_3^2}{(\delta - z_1)^2} - k(z_1 - d) - bz_2\right) - \frac{5m}{7}\left(mg\sin\phi + \frac{c(z_3^e)^2}{(\delta - z_1^e)^2} - k(z_1^e - d)\right)$$
$$\dot{z}_3 = \frac{V - z_3 R}{L_0 + L_1 e^{-\alpha(\delta - z_1)}} - \frac{v^e - z_3^e R}{L_0 + L_1 e^{-\alpha(\delta - z_1^e)}}$$

* SHOW This part at A4 Start

A4 → ∗ $\dot{z}_1 = z_2 - z_2^e$ ∗

$$\dot{z}_2 = \cancel{\frac{5m}{7}\sin\phi} + \frac{5mc}{7}\left[\frac{z_3^2}{(\delta - z_1)^2}\right] - \frac{5mkz_1}{7} + \cancel{\frac{5mkd}{7}} - \frac{5mbz_2}{7}$$

$$- \cancel{\frac{5m\,mg\sin\phi}{7}} - \frac{5mc}{7}\left[\frac{(z_3^e)^2}{(\delta - z_1^e)^2}\right] + \frac{5mkz_1^e}{7} - \cancel{\frac{5mkd}{7}}$$

∗ $\dot{z}_2 = \frac{5m}{7}\left[c\left(\frac{z_3^2}{(\delta - z_1)^2} - \frac{(z_3^e)^2}{(\delta - z_1^e)^2}\right) - k(z_1 - z_1^e) - bz_2\right]$ ∗

$$\dot{z}_3 = \frac{V - z_3 R}{L_0 + L_1 e^{\alpha(z_1 - \delta)}} - \frac{V^e - z_3^e R}{L_0 + L_1 e^{\alpha(z_1^e - \delta)}}$$

$$\boxed{\begin{aligned} \dot{z}_1 &= z_2 - z_2^e \\ \dot{z}_2 &= \frac{5m}{7}\left[c\left(\frac{z_3^2}{(\delta - z_1)^2} - \frac{(z_3^e)^2}{(\delta - z_3^e)^2}\right) - k(z_1 - z_1^e) - bz_2\right] \\ \dot{z}_3 &= \frac{V - z_3 R}{L_0 + L_1 e^{\alpha(z_1 - \delta)}} - \frac{V^e - z_3^e R}{L_0 + L_1 e^{\alpha(z_1^e - \delta)}} \end{aligned}}$$