θ_{ss}

F_H

$-k\theta_{ss}$

$\downarrow \theta_{ss}$

$\underline{F}_{ext}$

$\Sigma F = m a_{sp} \quad F_H = m_{sp} a_{sp}$

At steady state, we know that

$\Sigma \tau_H = 0$ because $\ddot{\theta} = 0$. Therefore,

$$\Sigma \tau_{CoM} = \underbrace{-k\theta_{pax}}_{} - \overbrace{m_{sp} a_{sp}}^{F} \underbrace{(d \cos \theta_{ss})}_{r} = I\ddot{\theta}$$

$$a_{sp} = \frac{F}{m_{sc}}$$

$$-k\theta_{ss} = m_{sp} \left(\frac{F}{m_{sc}} \right) d \cos \theta_{ss}$$

$$f(\theta) = k\theta_{ss} + m_{sp} a_{sp} (d \cos \theta_{ss})$$