$$\frac{I_w}{R^2}\frac{d^2x_w(t)}{dt^2} + (M_r + M_w)\frac{d^2x_w(t)}{dt^2} + hm_b\sin(\theta(t))\left(\frac{d\theta(t)}{dt}\right)^2 - hm_b\cos(\theta(t))\frac{d^2\theta(t)}{dt^2}$$

$$+ m_b r\sin(\theta(t))\left(\frac{d\theta(t)}{dt}\right)^2 - m_b r\cos(\theta(t))\frac{d^2\theta(t)}{dt^2} - m_b x(t)\sin(\theta(t))\frac{d^2\theta(t)}{dt^2}$$

$$- m_b x(t)\cos(\theta(t))\left(\frac{d\theta(t)}{dt}\right)^2 - 2m_b\sin(\theta(t))\frac{d\theta(t)}{dt}\frac{dx(t)}{dt} + m_b\cos(\theta(t))\frac{d^2x(t)}{dt^2} + m_b\frac{d^2x_w(t)}{dt^2} = 0$$

$$\tag{1}$$

$$I_r\frac{d^2\theta(t)}{dt^2} + g\left[M_r d\cos(\theta(t)) - m_b\big((h+r)\sin(\theta(t)) - x(t)\cos(\theta(t))\big)\right]$$

$$+ h^2 m_b\frac{d^2\theta(t)}{dt^2} + 2hm_b r\frac{d^2\theta(t)}{dt^2} - hm_b\cos(\theta(t))\frac{d^2x_w(t)}{dt^2} - hm_b\frac{d^2x(t)}{dt^2}$$

$$+ m_b r^2\frac{d^2\theta(t)}{dt^2} - m_b r\cos(\theta(t))\frac{d^2x_w(t)}{dt^2} - m_b r\frac{d^2x(t)}{dt^2} + m_b x^2(t)\frac{d^2\theta(t)}{dt^2}$$

$$- m_b x(t)\sin(\theta(t))\frac{d^2x_w(t)}{dt^2} + 2m_b x(t)\frac{d\theta(t)}{dt}\frac{dx(t)}{dt} = 0$$

$$\tag{2}$$

$$\frac{I_b}{r^2}\frac{d^2x(t)}{dt^2} + gm_b\sin(\theta(t)) - hm_b\frac{d^2\theta(t)}{dt^2} - m_b r\frac{d^2\theta(t)}{dt^2} - m_b x(t)\left(\frac{d\theta(t)}{dt}\right)^2$$

$$+ m_b\cos(\theta(t))\frac{d^2x_w(t)}{dt^2} + m_b\frac{d^2x(t)}{dt^2} = 0$$

$$\tag{3}$$