1. Downright position linearized model · without spring

$$J_{eq} + m_2 l_1^2$$

$$\begin{cases} (m_1 x_1^2 + m_2 l_1^2 + I_1)\ddot{\vartheta}_1 + m_2 l_1 x_2 \ddot{\vartheta}_2 + (K_{F,1} + \frac{K_m^2}{R_m})\dot{\vartheta}_1 = \frac{K_m}{R_m} V_{IN} \\ m_2 l_1 x_2 \ddot{\vartheta}_1 + (m_2 x_2^2 + I_2)\ddot{\vartheta}_2 + K_{F,2}\dot{\vartheta}_2 + m_2 g x_2 \vartheta_2 = 0 \end{cases}$$

2. Downright position linearized model · with spring

$$J_{eq} + m_2 l_1^2$$

$$\begin{cases} (m_1 x_1^2 + m_2 l_1^2 + I_1)\ddot{\vartheta}_1 + m_2 l_1 x_2 \ddot{\vartheta}_2 + (K_{F,1} + \frac{K_m^2}{R_m})\dot{\vartheta}_1 + K_S \vartheta_1 = \frac{K_m}{R_m} V_{IN} \\ m_2 l_1 x_2 \ddot{\vartheta}_1 + (m_2 x_2^2 + I_2)\ddot{\vartheta}_2 + K_{F,2}\dot{\vartheta}_2 + m_2 g x_2 \vartheta_2 = 0 \end{cases}$$

3. Experiment #1 : fixed ϑ_2 · without spring

$$J_{eq} + m_2 l_1^2$$

$$(m_1 x_1^2 + m_2 l_1^2 + I_1)\ddot{\vartheta}_1 + (K_{F,1} + \frac{K_m^2}{R_m})\dot{\vartheta}_1 = \frac{K_m}{R_m} V_{IN}$$

4. Experiment #1 : fixed ϑ_2 · with spring

$$J_{eq} + m_2 l_1^2$$

$$(m_1 x_1^2 + m_2 l_1^2 + I_1)\ddot{\vartheta}_1 + (K_{F,1} + \frac{K_m^2}{R_m})\dot{\vartheta}_1 + K_S \vartheta_1 = \frac{K_m}{R_m} V_{IN}$$

EXTRA. Experiment #2 : fixed ϑ_1

$$(m_2 x_2^2 + I_2)\ddot{\vartheta}_2 + K_{F,2}\dot{\vartheta}_2 + m_2 g x_2 \vartheta_2 = 0$$

5. Upright position linearized model without spring

$J_{eq} + m_2 l_1^2$

$$\begin{cases} (m_1 x_1^2 + m_2 l_1^2 + I_1)\ddot{\vartheta}_1 - m_2 l_1 x_2 \ddot{\vartheta}_2 + \left(K_{F,1} + \frac{K_m^2}{R_m}\right)\dot{\vartheta}_1 = \frac{K_m}{R_m} V_{IN} \\ -m_2 l_1 x_2 \ddot{\vartheta}_1 + (m_2 x_2^2 + I_2)\ddot{\vartheta}_2 + K_{F,2}\dot{\vartheta}_2 - m g x_2 \vartheta_2 = 0 \end{cases}$$

6. Upright position linearized model with spring

$J_{eq} + m_2 l_1^2$

$$\begin{cases} (m_1 x_1^2 + m_2 l_1^2 + I_1)\ddot{\vartheta}_1 - m_2 l_1 x_2 \ddot{\vartheta}_2 + \left(K_{F,1} + \frac{K_m^2}{R_m}\right)\dot{\vartheta}_1 + K_S \vartheta_1 = \frac{K_m}{R_m} V_{IN} \\ -m_2 l_1 x_2 \ddot{\vartheta}_1 + (m_2 x_2^2 + I_2)\ddot{\vartheta}_2 + K_{F,2}\dot{\vartheta}_2 - m g x_2 \vartheta_2 = 0 \end{cases}$$

7. Nonlinear model

J_{eq}

$$\begin{cases} \left[m_1 x_1^2 + I_1 + m_2 (l_1^2 + x_2^2 s_2^2)\right]\ddot{\vartheta}_1 + m_2 l_1 x_2 c_2 \ddot{\vartheta}_2 + \\ + 2 m_2 x_2^2 s_2 c_2 \dot{\vartheta}_1 \dot{\vartheta}_2 - m_2 l_1 x_2 s_2 \dot{\vartheta}_2^2 + K_S \vartheta_1 = \\ = K_m / R_m \cdot V_{IN} - K_m^2 / R_m \cdot \dot{\vartheta}_1 - K_{F,1} \cdot \dot{\vartheta}_1 \\ \\ m_2 l_1 x_2 c_2 \ddot{\vartheta}_1 + (m_2 x_2^2 + I_2)\ddot{\vartheta}_2 - m_2 x_2^2 s_2 c_2 \dot{\vartheta}_1^2 + m_2 g x_2 s_2 = \\ = -K_{F,2}\dot{\vartheta}_2 \end{cases}$$

8. Motor equation

$$\tau = \frac{K_m}{R_m} \cdot (V_{IN} - K_m \dot{\vartheta}_1)$$