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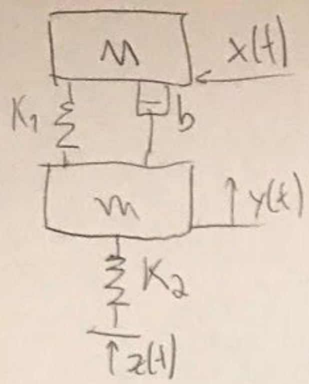
2)

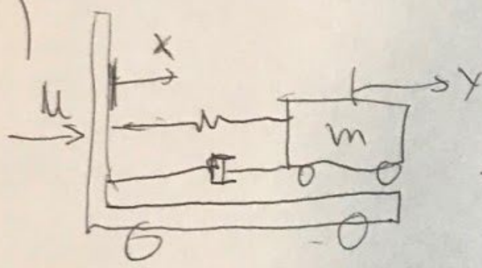
$$X = [x\ \cancel{y}\ \dot{x}\ \dot{y}]^T \Rightarrow \dot{X} = [\dot{x}\ \dot{y}\ \ddot{x}\ \ddot{y}]^T$$



$$\Rightarrow \begin{cases} M\ddot{x} + K_1(x-y) + b(\dot{x}-\dot{y}) = 0 \\ m\ddot{y} - K_1(x-y) - b(\dot{x}-\dot{y}) + K_2(y-z) = 0 \end{cases}$$

$$\Rightarrow \dot{X} = \begin{bmatrix} 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \\ -\frac{K_1}{M} & \frac{K_1}{M} & -\frac{b}{M} & \frac{b}{M} \\ \frac{K_1}{M} & \frac{-K_1-K_2}{m} & \frac{b}{M} & \frac{-b}{m} \end{bmatrix} X + \begin{bmatrix} 0 \\ 0 \\ 0 \\ \frac{K_2}{M} \end{bmatrix} Z$$

3)



$$\Rightarrow \begin{cases} m\ddot{y} + K(y-x) + b(\dot{y}-\dot{x}) = 0 \\ M\ddot{x} - K(y-x) - b(\dot{y}-\dot{x}) = u \end{cases}$$

$$\Rightarrow \begin{cases} X = [x\ y\ \dot{x}\ \dot{y}]^T \\ \dot{X} = [\dot{x}\ \dot{y}\ \ddot{x}\ \ddot{y}]^T \end{cases} \Rightarrow \dot{X} = \begin{bmatrix} 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \\ -\frac{K}{M} & \frac{K}{M} & -\frac{b}{M} & \frac{b}{M} \\ \frac{K}{M} & -\frac{K}{M} & \frac{b}{M} & \frac{-b}{M} \end{bmatrix} X + \begin{bmatrix} 0 \\ 0 \\ \frac{1}{M} \\ 0 \end{bmatrix} u$$

4)

$$X = [x_1\ x_2\ x_G\ \theta\ \dot{x}_1\ \dot{x}_2\ \dot{x}_G\ \dot{\theta}]^T \Rightarrow \dot{X} = [\dot{x}_1\ \dot{x}_2\ \dot{x}_G\ \dot{\theta}\ \ddot{x}_1\ \ddot{x}_2\ \ddot{x}_G\ \ddot{\theta}]^T$$

$$\Rightarrow \dot{X} = AX + BU$$

$$\Rightarrow A = \begin{bmatrix} 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \\ \frac{-(K+K_1)}{m_1} & 0 & \frac{K_1}{m_1} & \frac{K_1 l}{m_1} & -\frac{K_1}{m_1} & 0 & \frac{b_1}{m_1} & \frac{b_1 l}{m_1} \\ 0 & \frac{-(K_1+K)}{m_2} & \frac{K_2}{m_2} & \frac{-K_2 l}{m_2} & 0 & \frac{-b_2}{m_2} & \frac{b_2}{m_2} & \frac{-b_2 l}{m_2} \\ \frac{K_1}{M} & \frac{K_2}{M} & \frac{-(K_1+K_2)}{M} & \frac{(K_2-K_1)l}{M} & \frac{b_1}{M} & \frac{b_2}{M} & \frac{-(b_1+b_2)}{M} & \frac{(b_2-b_1)l}{M} \\ \frac{K_1 l}{J} & \frac{-K_2 l}{J} & \frac{l(K_2-K_1)}{J} & \frac{-l^2(K_2+K_1)}{J} & \frac{b_1 l}{J} & \frac{-b_2 l}{J} & \frac{l(b_2-b_1)}{J} & \frac{-l^2(b_2-b_1)}{J} \end{bmatrix}$$

5) $X = [x \ \theta \ \dot{x} \ \dot{\theta}]^T \Rightarrow \dot{X} = [\dot{x} \ \dot{\theta} \ \ddot{x} \ \ddot{\theta}]^T$

$$\Rightarrow \begin{cases} (M+m)\ddot{x} + ml\ddot{\theta} = u \\ J\ddot{\theta} + ml\ddot{x} - mgl\theta = 0 \end{cases}$$

$$\Rightarrow A = \begin{bmatrix} 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & \frac{-m^2 l^2}{J(M+m) - m^2 l^2} & 0 & 0 \\ 0 & \frac{mgl(M+m)}{J(M+m)^2 - m^2 l^2} & 0 & 0 \end{bmatrix} ; \quad B = \begin{bmatrix} 0 \\ 0 \\ \frac{1}{M+m-\frac{m^2 l^2}{J}} \\ \frac{-mgl}{J(M+m) - m^2 l^2} \end{bmatrix}$$

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6) $X = [x \ \dot{x} \ I]^T \Rightarrow \dot{X} = [\dot{x} \ \ddot{x} \ \dot{I}]^T$

$$\Rightarrow A = \begin{bmatrix} 0 & 1 & 0 \\ \frac{2KI_0^2}{m x_0^3} & 0 & \frac{-2KI_0}{m x_0^2} \\ 0 & 0 & -R/L \end{bmatrix} ; \quad B = \begin{bmatrix} 0 \\ 0 \\ \frac{1}{L} \end{bmatrix}$$

com $\dot{X} = A\dot{X} + Bu$