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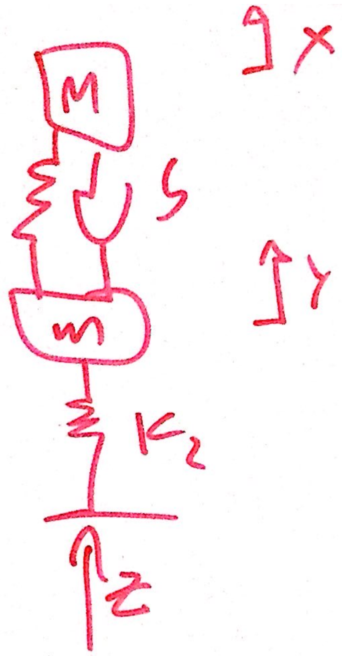
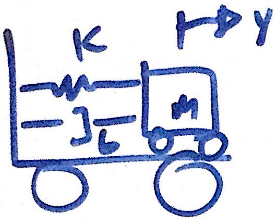
2)



$$\begin{cases} M\ddot{x} + K_1(x-y) + b(\dot{x}-\dot{y}) = 0 \\ m\ddot{y} - K_1(x-y) - b(\dot{x}-\dot{y}) + k_2(y-z) = 0 \end{cases}$$

$$\begin{bmatrix} 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \\ -\frac{K_1}{M} & \frac{K_1}{M} & \frac{-b}{M} & \frac{b}{M} \\ \frac{K_1}{m} & -\frac{K_1+K_2}{m} & \frac{b}{m} & \frac{-b}{m} \end{bmatrix} \begin{bmatrix} x \\ y \\ \dot{x} \\ \dot{y} \end{bmatrix} + \begin{bmatrix} 0 \\ 0 \\ 0 \\ \frac{k}{m} \end{bmatrix} z = \begin{bmatrix} \dot{x} \\ \dot{y} \\ \ddot{x} \\ \ddot{y} \end{bmatrix}$$



$$M\ddot{x} - k(y-x) - b(\dot{y}-\dot{x}) = u$$

$$m\ddot{y} + K(y-x) + b(\dot{y}-\dot{x}) = 0$$

$$\begin{bmatrix} 0 \\ 0 \\ \frac{1}{M} \\ 0 \end{bmatrix} u + \begin{bmatrix} 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \\ -K/M & K/M & -b/M & b/M \\ K/m & -K/m & b/m & -b/m \end{bmatrix} \begin{bmatrix} \dot{x} \\ \dot{y} \\ \ddot{x} \\ \ddot{y} \end{bmatrix} = \begin{bmatrix} X \\ Y \\ \dot{X} \\ \dot{Y} \end{bmatrix}$$

4) vetor de estados: $\dot{x} = Ax + BU$, $U = [z(t), z(t+\alpha)]$

$$m_1\ddot{x}_1 + K(x_1 - z) - K_1(x_E - x_1 + l\theta) - b_1(\dot{x}_E - \dot{x}_1 + l\dot{\theta}) = 0$$

$$m_2\ddot{x}_2 + K(x_2 - z) - K_2(x_E - x_2 + l\theta) - b_2(\dot{x}_E - \dot{x}_2 - l\dot{\theta}) = 0$$

$$M\ddot{x}_E + K_1(x_E - x_1 + l\theta) + K_2(\dot{x}_E + \dot{x}_2 - l\dot{\theta}) + b_2(x_E - x_2 - l\dot{\theta}) = 0$$

$$J_E\ddot{\theta} + K_1 l(x_E - x_1 + l\theta) - K_2 l(x_E - x_2 - l\theta) + b_1 l(\dot{x}_E - \dot{x}_1 + l\theta) + b_2 l(\dot{x}_E - \dot{x}_2 - l\dot{\theta}) = 0$$

ex 5)

$$\begin{pmatrix} 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & -m^2 l^2/(J(M+m)-m^2 l^2) & 0 & 0 \\ 0 & g m l (M+m)/(J(M+m)-m^2 l^2) & 0 & 0 \end{pmatrix} = A$$

$$\begin{pmatrix} 0 \\ 0 \\ \dfrac{1}{M+m-\dfrac{m^2 l^2}{J}} \\ \dfrac{-g m l}{J(M+m)-m^2 l^2} \end{pmatrix} = B \qquad \boxed{\dot{X} = AX + Bu}$$

6)

$$A = \begin{bmatrix} 0 & 1 & 0 \\ \frac{2kI_0^2}{m x_0^3} & 0 & -\frac{2kI_0}{m x_0^2} \\ 0 & 0 & -\frac{R}{L} \end{bmatrix} ; \quad B = \begin{pmatrix} 0 \\ 0 \\ \frac{1}{L} \end{pmatrix}$$

$$\boxed{\dot{x} = Ax + Bu} ; \quad x = \begin{bmatrix} x \\ \dot{x} \\ I \end{bmatrix} \quad \boxed{u = V}$$