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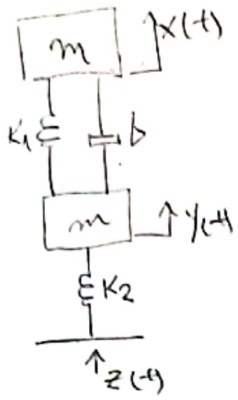
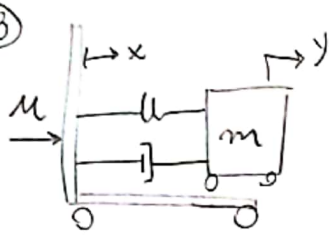
②



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

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

③



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

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

④ $\dot{x} = Ax + BU$, $U = [z(t), z(t-\alpha_1)]$

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

$$m_2\ddot{x}_2 + K(x_2 - z') - K_2(x_\epsilon - x_2 + l\theta) - b_2(\dot{x}_\epsilon - \dot{x}_2 - l\dot{\theta}) = 0$$

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

$$J_\epsilon\ddot{\theta} + K_1 l(x_\epsilon - x_1 + l\theta) - K_2 l(x_\epsilon - x_2 - l\theta) + b_1 l(\dot{x}_\epsilon - x_1 + l\theta) + b_2 l(\dot{x}_\epsilon - \dot{x}_2 - l\dot{\theta}) = 0$$

(5)

$$\begin{bmatrix} 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & \frac{-m^2l^2}{J(M+m)-m^2l^2} & 0 & 0 \\ 0 & \frac{8ml(M+m)}{J(M+m)-m^2l^2} & 0 & 0 \end{bmatrix} = A$$

$$\begin{bmatrix} 0 \\ 0 \\ \frac{1}{M+m-\frac{m^2l^2}{J}} \\ \frac{-8ml}{J(M+m)-m^2l^2} \end{bmatrix} = B \qquad \dot{x} = Ax + Bu$$

(6)

$$A = \begin{bmatrix} 0 & 1 & 0 \\ \frac{2KI_D^2}{mx_0^3} & 0 & \frac{-2KI_0}{mx_0^2} \\ 0 & 0 & -K/L \end{bmatrix}, \qquad B = \begin{bmatrix} 0 \\ 0 \\ 1/L \end{bmatrix}$$

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