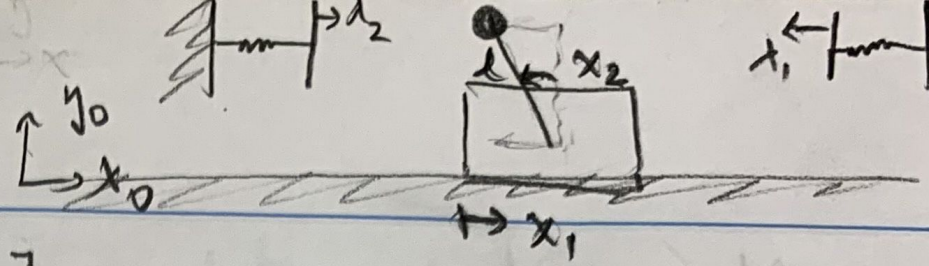


pos: m_c: $\begin{bmatrix} x_1 \\ 0 \end{bmatrix}$

m_p: $\begin{bmatrix} -l\sin(x_2) + x_1 \\ l\cos(x_2) \end{bmatrix}$

vel: m_c: $\begin{bmatrix} \dot{x}_1 \\ 0 \end{bmatrix}$

m_p: $\begin{bmatrix} -l\cos(x_2)\dot{x}_2 + \dot{x}_1 \\ -l\sin(x_2)\dot{x}_2 \end{bmatrix}$

$L = K - P$

$$K = \frac{1}{2} m_c \dot{x}_1^2 + \frac{1}{2} m_p \left[(-l\cos(x_2)\dot{x}_2 + \dot{x}_1)^2 + (-l\sin(x_2)\dot{x}_2)^2 \right]$$

$$P = m_p g l \cos(x_2)$$

$$L = \frac{1}{2} m_c \dot{x}_1^2 + \frac{1}{2} m_p \left[(-l\cos(x_2)\dot{x}_2 + \dot{x}_1)^2 + (-l\sin(x_2)\dot{x}_2)^2 \right] + \frac{1}{2} I \dot{x}_2 - m_p g l \cos(x_2)$$

$$= \frac{1}{2} m_c \dot{x}_1^2 + \frac{1}{2} m_p \left[l^2 \dot{x}_2^2 - l\cos(x_2)\dot{x}_1 + \dot{x}_1^2 \right] - m_p g l \cos(x_2)$$

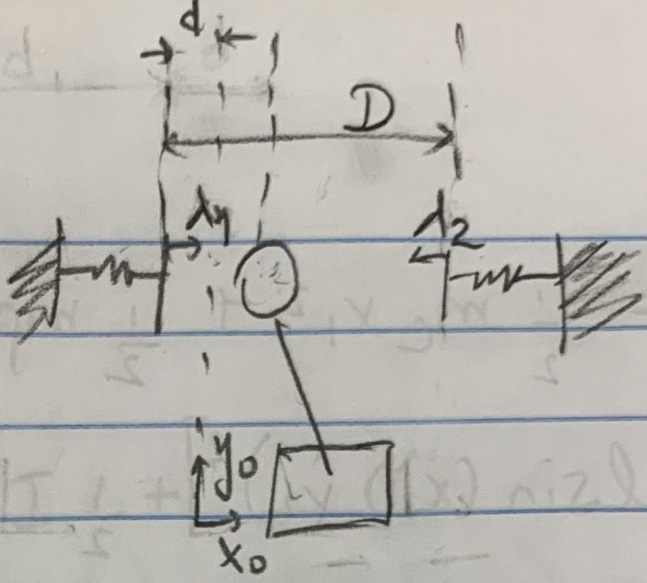
$$\frac{d}{dt}\frac{\partial L}{\partial \dot{x}_1} - \frac{\partial L}{\partial x_1} = \frac{d}{dt}\left[m_c \dot{x}_1 - \frac{m_p}{2} l\cos(x_2) + m_p \dot{x}_1 \right]$$

$$= \boxed{m_c \ddot{x}_1 + \frac{m_p}{2} l \sin(x_2)\dot{x}_2 + m_p \ddot{x}_1}$$

$$\frac{d}{dt}\frac{\partial L}{\partial \dot{x}_2} - \frac{\partial L}{\partial x_2} = \frac{d}{dt}\left[m_p l^2 \dot{x}_2 + I\dot{x}_2 \right] - \left[\frac{1}{2} m_p \sin(x_2)\dot{x}_1 + m_p g l \sin(x_2) \right]$$

$$= \boxed{(m_p l^2 + I)\ddot{x}_2 - \frac{m_p}{2} \sin(x_2)\dot{x}_1 + m_p g l \sin(x_2)}$$

$$\Rightarrow \begin{bmatrix} m_c + m_p & 0 \\ 0 & m_p l^2 + J \end{bmatrix} \ddot{x} + \begin{bmatrix} 0 & m_p l \sin(x_2)/2 \\ -\frac{m_p}{2}\sin(x_2) & 0 \end{bmatrix} \dot{x} + \begin{bmatrix} 0 \\ m_p g l \sin(x_2) \end{bmatrix} = \begin{bmatrix} u \\ 0 \end{bmatrix} + W^T d$$



$$g_1 = (x_1 - l\sin(x_2)) - \vec{d}$$

$$g_2 = D - g_1$$

$$\dot{g} = \begin{bmatrix} \dot{x}_1 - l\cos(x_2)\dot{x}_2 \\ -\dot{x}_1 + l\cos(x_2)\dot{x}_2 \end{bmatrix}$$

$$\dot{g} = W^T \dot{x} = \begin{bmatrix} 1 & -l\cos(x_2) \\ -1 & l\cos(x_2) \end{bmatrix} \begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \end{bmatrix}$$