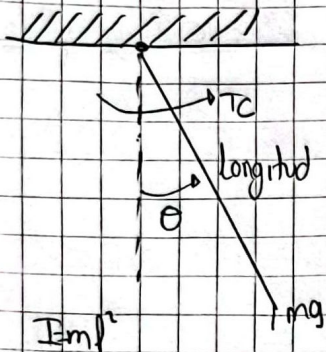


PENDULO



$$(M+m)\ddot{x} + ml\ddot{\theta} = u$$

$$(I+ml^2)\ddot{\theta} + ml\ddot{x} = mgl\theta$$

$$M\ddot{x} + m\ddot{x} + ml\ddot{\theta} = u$$

$$I\ddot{\theta} + ml^2\ddot{\theta} + ml\ddot{x} = mgl\theta$$

$$q_1 = x$$

$$q_2 = \dot{q}_1 = \dot{x}$$

$$\dot{q}_2 = \ddot{x}$$

$$q_3 = \theta$$

$$q_4 = \dot{q}_3 = \dot{\theta}$$

$$\dot{q}_4 = \ddot{\theta}$$

$$(M+m)\ddot{x} + ml\ddot{\theta} = u$$

$$\ddot{x} = \frac{u - ml\ddot{\theta}}{M+m} = \frac{u}{M+m} - \frac{ml}{(M+m)}\ddot{\theta}$$

$$\left(\frac{I+ml^2}{mgl}\right)\ddot{\theta} + \frac{ml\ddot{x}}{mgl} = \theta$$

$$\left(\frac{I+ml^2}{mgl}\right)\ddot{\theta} + \left(\frac{1}{g}\right)\left(\frac{u}{M+m} - \frac{ml}{M+m}\ddot{\theta}\right)$$

$$\left(\frac{I+ml^2}{mg^2l} - \frac{ml}{g(M+m)}\right)\ddot{\theta} + \frac{1}{g(M+m)}u = \theta$$

$$\left(\frac{I+ml^2}{mg^2l} - \frac{ml}{g(M+m)}\right)\ddot{\theta} = -\frac{1}{g(M+m)}u + \theta$$

$$\left(\frac{(I+ml^2)(g(M+m)) - ml(mg^2l)}{mg^2l(g(M+m))}\right)\ddot{\theta} = \theta - \frac{1}{g(M+m)}u$$

$$\frac{mg^2l(g(M+m))}{(I+ml^2)(g(M+m)) - ml(mg^2l)}\ddot{\theta} = \theta - \frac{mg^2l(g(M+m))}{mg^2l(g(M+m))}u$$

$$\frac{mg^2l(g(M+m))}{(I+ml^2)(g(M+m)) - ml(mg^2l)}\ddot{\theta} = \theta - \frac{1}{g(M+m)}u = \ddot{\theta}$$

$$\ddot{x} = \left(\frac{I + ml^2}{mgl} \right) \left(\frac{mg^2 l (g(M+m))}{(I + ml^2) (g(M+m)) - ml(mg^2 l)} \right) \theta - \frac{I + ml^2}{mg^2 l (M+m)} u$$

$$\begin{bmatrix} \ddot{q}_1 \\ \ddot{q}_2 \\ \ddot{q}_3 \\ \ddot{q}_4 \end{bmatrix} = \begin{bmatrix} 0 & 1 & 0 & 0 \\ 0 & 0 & \alpha & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & z & 0 \end{bmatrix} \begin{bmatrix} 0 \\ 1/g(M+m) \\ 0 \\ -1/g(M+m) \end{bmatrix} u$$

$$\alpha = \frac{I + ml^2}{mgl} \frac{mg^2 l (g(M+m))}{(I + ml^2) g(M+m) - ml(mg^2 l)}$$

$$z = \frac{mg^2 l (g(M+m))}{(I + ml^2) (g(M+m)) - mg^2 l}$$

$$\begin{bmatrix} x \\ \theta \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 \end{bmatrix} \begin{bmatrix} q_1 \\ q_2 \\ q_3 \\ q_4 \end{bmatrix}$$