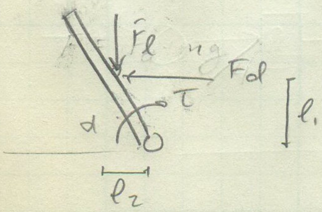
$W \otimes$



$$F_\ell = \overset{2\pi\alpha}{C_\ell} \cdot \overset{WL}{A} \cdot \rho \cdot \frac{\dot{x}^2}{2}$$

$$F_\ell = 2\pi\alpha \cdot WL \cdot \rho \cdot \frac{\dot{x}^2}{2}$$

$$F_\ell = C_1 \cdot \alpha \qquad \ddot{F}_\ell = C_1 \ddot{\alpha}$$

$$F_{dr} = C_d \cdot A \cdot \rho \cdot \frac{\dot{x}^2}{2}$$

$$F_{dr} = 1.28 \sin\alpha \cdot WL \cdot \rho \cdot \frac{\dot{x}^2}{2}$$

$$F_{dr} = C_2 \sin\alpha$$

$$\tau - F_\ell \ell_2 - F_d \cdot \ell_1 = J\ddot{\alpha}$$

$$\tau - (C_1 \cdot \alpha) \cos\alpha \frac{L}{2} - C_2 \sin^2(\alpha) \frac{L}{2} = J\ddot{\alpha}$$

$$\tau - \frac{C_1 L}{2}\left(\frac{\pi^2/4 + \alpha(\pi - 4)}{4\sqrt{2}}\right) - \frac{C_2 L}{2}\left(\alpha + \frac{1}{2} - \pi/4\right) = J\ddot{\alpha}$$

$$\boxed{\tau \triangleq \tilde{\tau} + \frac{C_1 L}{2}\left(\frac{\pi^2/4}{4\sqrt{2}}\right) + \frac{C_2 L}{2}\left(\frac{1}{2} - \pi/4\right)}$$

$$\tilde{\tau} - \frac{C_1 L}{8\sqrt{2}} \alpha(4 - \pi) - \frac{C_2 L}{2}\alpha = J\ddot{\alpha}$$

$$C_3 \triangleq +\frac{C_1 L}{8\sqrt{2}}(4 - \pi) \qquad C_4 \triangleq +\frac{C_2 L}{2}$$

$$C_5 \triangleq +(C_3 + C_4)$$

$$\tilde{\tau} - C_5 \alpha = J\ddot{\alpha}$$

$$\tilde{\tau} - C_5 \frac{\tilde{F}_\ell}{C_1} = \frac{J \cdot \ddot{\tilde{F}}_\ell}{C_1}$$

$\mathcal{L}$

$$\tilde{T}(s) - \frac{C_5}{C_1}\tilde{F}_\ell(s) = \frac{J}{C_1} \cdot s^2 \cdot \tilde{F}_\ell(s)$$

$$\tilde{T} = \tilde{F}_\ell(s)\left(\frac{J}{C_1}s^2 + \frac{C_5}{C_1}\right)$$

$$\boxed{\frac{\tilde{F}_\ell(s)}{\tilde{T}(s)} = \frac{1}{\frac{J}{C_1}s^2 + \frac{C_5}{C_1}}} \quad \boxed{A}$$

Linearize

$\alpha \cdot \cos^2(\alpha)$ @ 45°

$$\approx \frac{\pi - (\pi - 4)(\alpha - \pi/4)}{4\sqrt{2}}$$

$$\approx \frac{\frac{\pi^2}{4} + \alpha(4 - \pi)}{4\sqrt{2}}$$

$\sin^2(\alpha)$ @ $\pi/4$

$$\approx \frac{1}{2} + (\alpha - \pi/4)$$

Where:

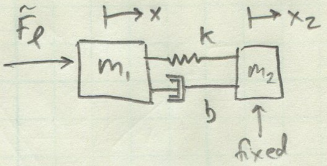
$C_1 = 2\pi WL\rho \frac{\dot{x}^2}{2}$

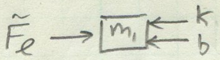
$C_2 = 1.28 \cdot WL\rho \frac{\dot{x}^2}{2}$

$C_3 = \frac{C_1 L}{8\sqrt{2}}(4 - \pi)$

$C_4 = \frac{C_2 L}{2}$

$C_5 = C_3 + C_4$

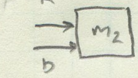




$$F_{NET1} = \tilde{F}_\ell - k(x_1) - b(\dot{x}_1) = m\ddot{x}_1$$

$$\tilde{F}_\ell(s) - k(X_1(s)) - bs(X_1(s) = s^2 m X_1(s)$$

$$\frac{X_1(s)}{\tilde{F}_\ell} = \frac{1}{ms^2+bs+k}$$



$$F_{NET2} = \Delta F_N = k(x_1) + b(\dot{x}_1)$$

$$\Delta F_N(s) = k X_1(s) + bs X_1(s)$$

$$\frac{\Delta F_N(s)}{X_1(s)} = k + bs$$

$$\frac{\Delta F_N}{\tilde{F}_\ell} = \frac{X_1(s)}{\tilde{F}_\ell} \cdot \frac{\Delta F_N(s)}{X_1(s)} = \frac{bs+k}{ms^2+bs+k}$$