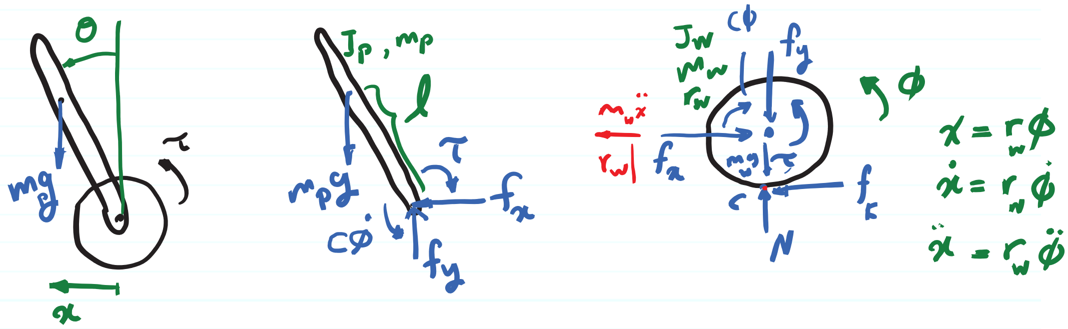


For the wheel:

$$\sum M_c = \tau - c\dot{\phi} - f_x r_w = J_w \ddot{\phi} + \overbrace{m_w \ddot{x}\, r_w}^{m\bar{a}d}$$

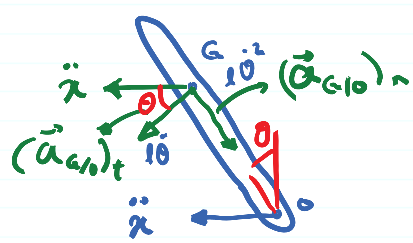
$$\Rightarrow \quad J_w \frac{\ddot{x}}{r_w} + m_w r_w \ddot{x} + c\frac{\dot{x}}{r_w} = \tau - f_x r_w \quad (1)$$

For the pendulum

$$\sum F_x = m_p \bar{a}_{p,x} \Rightarrow f_x = m_p \bar{a}_{p,x}$$

$$\bar{a}_{p,x} = \ddot{x} + l\ddot{\theta}\cos\theta - l\dot{\theta}^2\sin\theta$$

$$\left(\vec{a}_G = \vec{a}_o + (\vec{a}_{G/o})_t + (\vec{a}_{G/o})_n \right)$$



$$\Rightarrow f_x = m_p \ddot{x} + m_p l \ddot{\theta}\cos\theta - m_p l \dot{\theta}^2 \sin\theta \quad (2)$$

⇒ Eliminate f_x from (1) & (2) to get the first equation of motion

$\boxed{?}$ First EOM (1)

$$\sum M_o = J_p \ddot{\theta} + m_p \bar{a} d$$

$$\boxed{mgl\sin\theta + c\underbrace{\dot{\phi}}_{\frac{\dot{x}}{r_w}} - \tau = J_p\ddot{\theta} + m_p\left(\ddot{x}\, l\cos\theta + l^2\ddot{\theta}\right)} \quad (2)$$