



For the wheel:

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

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

For the pendulum

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

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

$$(\bar{\vec{a}}_G = \bar{\vec{a}}_O + (\bar{\vec{a}}_{G/O})_t + (\bar{\vec{a}}_{G/O})_n) \quad \text{Diagram showing acceleration components for the pendulum bob. The diagram shows the bob at an angle theta from the vertical. The acceleration vector is decomposed into tangential and normal components. The tangential component is labeled (a_G/O)_t and the normal component is labeled (a_G/O)_n. The total acceleration is labeled a. The angular displacement is theta and the angular velocity is theta-dot. The radius of the pendulum is l. The horizontal acceleration is labeled x.$$

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

$\Rightarrow$  Eliminate  $f_x$  from (1) & (2) to get the first equation of motion

? First EOM (1)

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

$$mgl \sin \theta + c \dot{\phi} - T = J_p \ddot{\theta} + m_p (\ddot{x} l \cos \theta + l^2 \ddot{\theta}) \quad (2)$$

$\downarrow$   
 $\frac{\dot{x}}{r_w}$

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