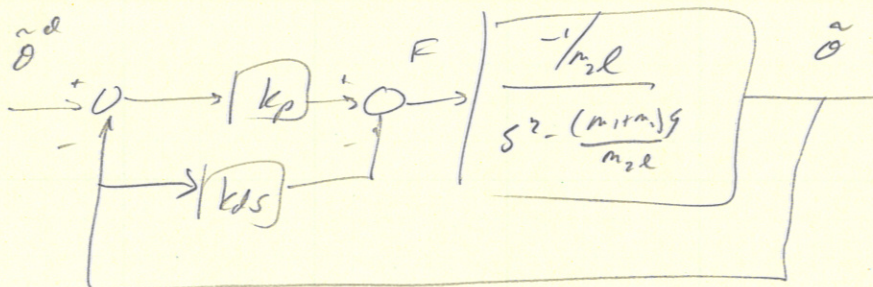


Inner Loop



The open loop transfer function is

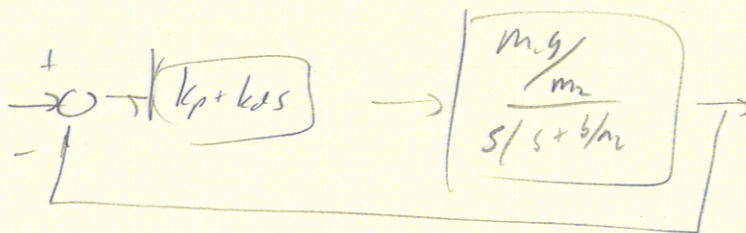
$$L(s) = (k_p + k_d s) \left(\frac{-1/m_2 l}{s^2 - \frac{(m_1 + m_2)g}{m_2}} \right)$$

∴ Type 0.

Can track a constant input with error

$$e_{ss} = \frac{A}{1 + \lim_{s \rightarrow 0} L(s)} = \frac{A}{1 + \left(\frac{k_p/m_2 l}{-(m_1 + m_2)g/m_2} \right)} = \frac{A}{1 + \frac{k_p}{(m_1 + m_2)g}}$$

b) Outer Loop



The open loop transfer function is

$$L(s) = (k_p + k_d s) \left(\frac{m_2 g / m}{s(s + b/m_2)} \right)$$

∴ Type 1 → track step with zero ss error

track ramp with error

$$\lim_{s \rightarrow 0} s L(s) = \frac{A}{\frac{k_p m_2 g / m}{b/m_2}} = \frac{A b}{k_p m_2 g}$$