



pend input  $\rightarrow \theta$   
cart input  $\rightarrow x$

$$T_{cl} = \frac{G(s) K(s)}{1 + G(s) K(s)}$$

$$P + I \frac{1}{s} + D \frac{N}{1 + N \frac{1}{s}}$$

$$T_{cl_{pend}} = \frac{G_{pend}(s) \cdot K_{pend}(s)}{1 + G_{pend}(s) \cdot K_{pend}(s)} = \frac{G_{pend}(s) \cdot \left( P + I \frac{1}{s} + D \cdot \frac{N}{1 + N \frac{1}{s}} \right)}{1 + G_{pend}(s) \cdot \left( P + I \frac{1}{s} + D \cdot \frac{N}{1 + N \frac{1}{s}} \right)}$$

$$L_{pend} = G_{pend}(s) \cdot K_{end}(s) \\ = G_{pend}(s) \cdot \left( P + I \frac{1}{s} + D \cdot \frac{N}{1 + N \frac{1}{s}} \right)$$

$$T_{cl_{cart}} = \frac{G_{cart}(s) \cdot K_{cart}(s)}{1 + G_{cart}(s) \cdot K_{cart}(s)} = \frac{G_{cart}(s) \cdot \left( P + I \frac{1}{s} + D \cdot \frac{N}{1 + N \frac{1}{s}} \right)}{1 + G_{cart}(s) \cdot \left( P + I \frac{1}{s} + D \cdot \frac{N}{1 + N \frac{1}{s}} \right)}$$

$$L_{cart} = G_{cart}(s) \cdot K_{cart}(s) \\ = G_{cart}(s) \cdot \left( P + I \frac{1}{s} + D \cdot \frac{N}{1 + N \frac{1}{s}} \right)$$