I. Review from Wed

A. Use PI properties
   - Avoid amplifying r by using y for derivative
   - Filter derivative to attenuate high frequency noise
   - Integral action to offset disturbances and model error

B. Integral Feedback

Claim: if system is stable, \( e \to 0 \) (even \( w \) does not go to 0)

"LP" if stable, then \( \int s dt \to 0 \) (\( x_e, u_e \))

\[ u = k_pe + k_de + k_ife \]

If \( e \neq 0 \) then \( u \to \infty \) \( \Rightarrow e \to 0 \)

Note: integral action is much more general than PID \( u = y_0 - k(x-x_0) - k_e \frac{dy}{dx} \)

C. Loop shaping w/ PID

[Diagram showing gain and phase response]

II. Controller implementation

\[ G(s) \rightarrow C(sI - A)^{-1}B + D \]

\[ \dot{x} = Ax + Bu \]

\[ y = Cx + Du \]

"realization"

\[ \dot{x} = \lim_{h \to 0} \frac{x(t+h) - x(t)}{h} \]

\[ x(t+h) = x(t) + hf(t) \]

\[ y(t) = h(x, u) \]

Implement on computer w/ fixed sampling time \( \Delta t = h \)