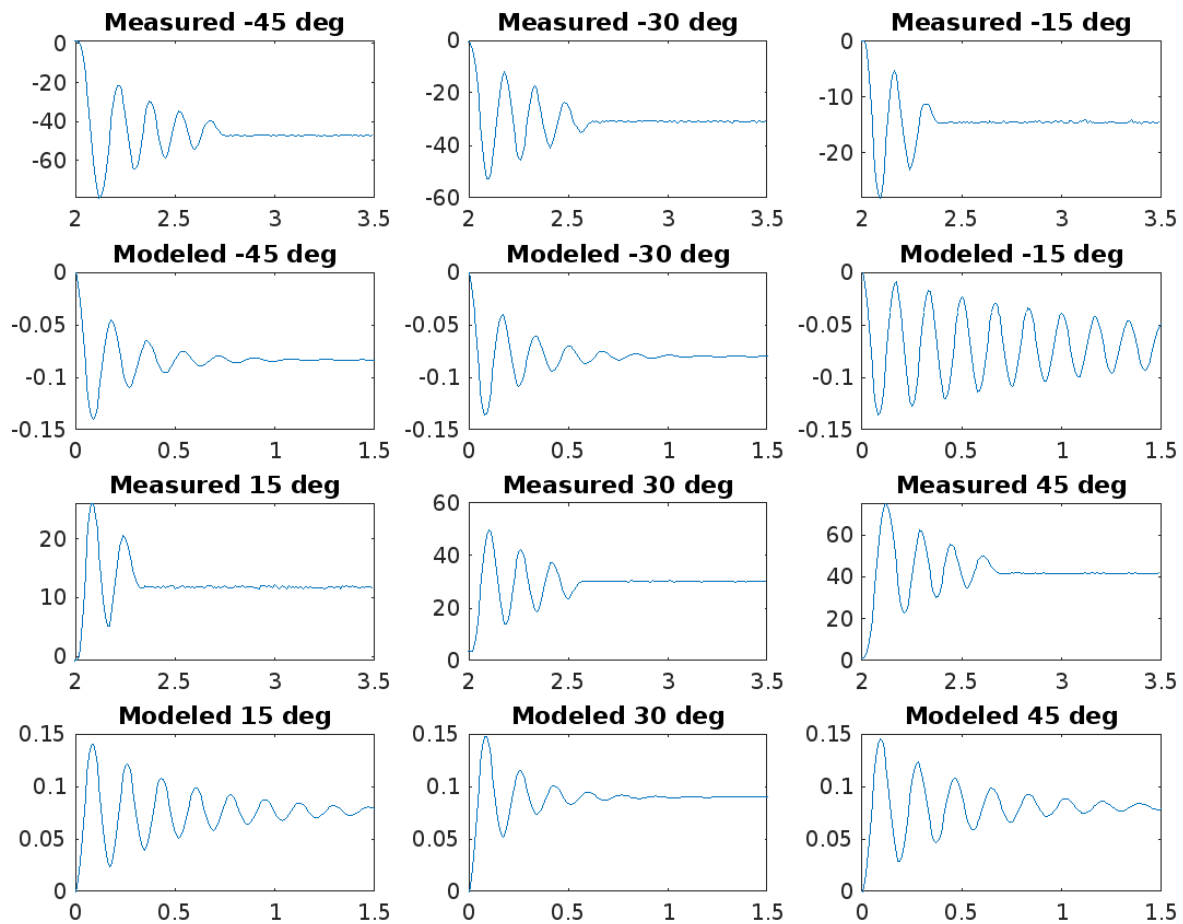


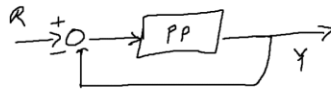
Problem 1:



Problem 2:

$$PID = \frac{s^2 K_d + s K_p + K_i}{s}$$

$$Plant = \frac{K \omega_n^2}{s^2 + 2\zeta \omega_n s + \omega_n^2} =$$



$$PP = \frac{s^2 K_d + s K_p + K_i}{s} \cdot \frac{1237}{s^2 + 8.56s + 1237}$$

$$= \frac{(1237 K_d) s^2 + (1237 K_p) s + (1237 K_i)}{s^3 + 8.56s^2 + 1237s}$$



$$TF = \frac{PP}{1+PP} = \frac{(1237 K_d) s^2 + (1237 K_p) s + (1237 K_i)}{(s^3 + 8.56s^2 + 1237s) + (1237 K_d) s^2 + (1237 K_p) s + (1237 K_i)}$$

$$= \frac{(1237 K_d) s^2 + (1237 K_p) s + (1237 K_i)}{s^3 + (1237 K_d + 8.56) s^2 + (1237 K_p + 1237) s + (1237 K_i)}$$

Req. 5

1) No ss error \rightarrow use I term ✓

2) $0.5\% < 5 \rightarrow 0.05 > e^{-\frac{\pi \zeta}{\sqrt{1-\zeta^2}}} \Rightarrow \ln(0.05) > \frac{-\pi \zeta}{\sqrt{1-\zeta^2}} \Rightarrow 3 < \frac{\pi \zeta}{\sqrt{1-\zeta^2}}$

3) $t_{ss} < 0.5 \text{ sec} \rightarrow \frac{4}{\zeta \omega_n} < 0.5$

$$\frac{4}{\omega_n} < 0.345$$

$$\frac{\omega_n}{4} > 2.90$$

$$\omega_n > 11.59$$

$$\Rightarrow 9 < \frac{\pi^2 \zeta^2}{1-\zeta^2} \Rightarrow 9 - 9\zeta^2 < \pi^2 \zeta^2$$

$$9 < (\pi^2 + 9) \zeta^2$$

$$\frac{9}{\pi^2 + 9} < \zeta^2 \Rightarrow \zeta > \frac{3}{\sqrt{\pi^2 + 9}} = 0.6906$$

want: $(s+a)(s^2 + 2\zeta \omega_n s + \omega_n^2)$

$$= (s+a)(s^2 + 16s + 134.6)$$

$$= s^3 + (16+a)s^2 + (134.6+16a)s + 134.6a$$

actual: $s^3 + (1237 K_d + 8.56)s^2 + (1237 K_p + 1237)s + (1237 K_i)$

PI: $K_i = 0 \Rightarrow 16+a = 8.56 \quad 134.6+16a = 1237 K_p + 1237 \quad 134.6a = 1237 K_i$

$$a = -7.44$$

$$\Rightarrow s+a \rightarrow s = -7.44 \Rightarrow \text{No good}$$

PID $\Rightarrow 16+a = 1237 K_d + 8.56 \quad 134.6+16a = 1237 K_p + 1237 \quad 134.6a = 1237 K_i$

let $a=4$:

$$20 = 1237 K_d + 8.56 \Rightarrow K_d = 0.009248$$

$$134.6+64 = 1237 K_p + 1237 \Rightarrow K_p = -0.8394$$

$$598.4 = 1237 K_i \Rightarrow K_i = 0.4352$$

* Negative $K_p \Rightarrow$ under-shoot

\rightarrow let $a = 117$

$$\Rightarrow K_d = 0.1006$$

$$K_p = 0.6222$$

$$K_i = 12.731$$

Problem 3:

