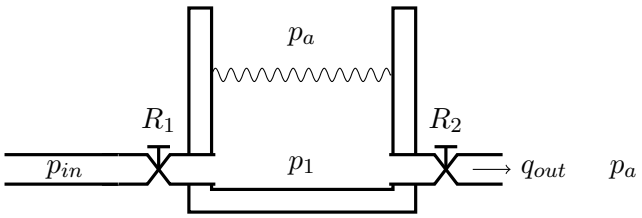
EENG307: Intro to Feedback Control

Fall 2020

Homework Assignment #5

Due: 11:59pm, Monday, Oct 5th, 2020.

1. Consider the following system, which has a variable supply pressure p_{in}



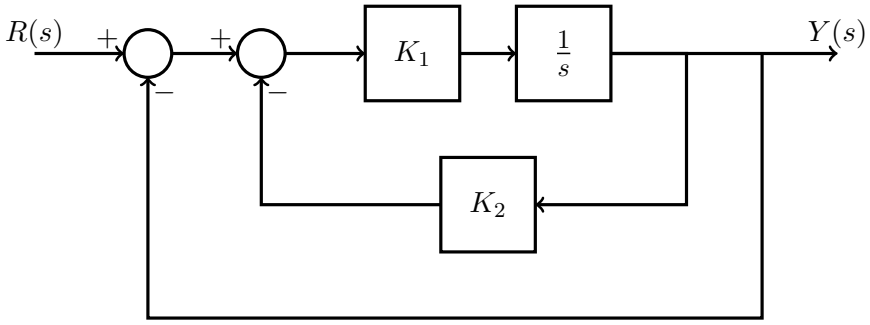
Tank Area: A

   (a) Find the impedance network that describes this system, considering p_a as ground.

   (b) Find the transfer function $P_1(s)/P_{in}(s)$.

   (c) Find an equation that the parameters R_1, R_2, A, ρ, and g should satisfy in order that the step response settling time $t_s < 10$s

2. Consider the following feedback system:



   Find K_1 and K_2 such that for a unit step input ($r(t) = u(t)$) the final value of the output $y(t)$ is 0.9 and the 1% settling time is 5 seconds. Hint: find $\frac{Y(s)}{R(s)}$, and from this K, and either σ or ζ and ω_n in terms of K_1 and K_2.

3. Suppose the specifications for the desired closed loop behavior of a feedback system are

   - Step response rise time $t_r < .5$ s
   - Step response settling time $t_s < 2$ s
   - Step response max overshoot %OS$< 20\%$

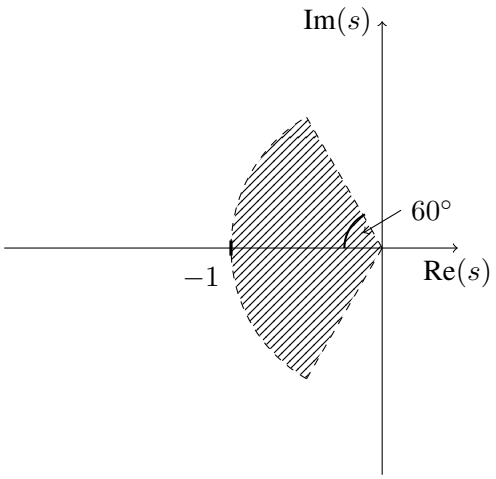
   Determine the acceptable range of values for ζ and ω_n of the closed loop poles that meet the step response transient specifications, and sketch the region in the complex plane where these poles can lie.

4. For the following problem, we will be considering a second order system

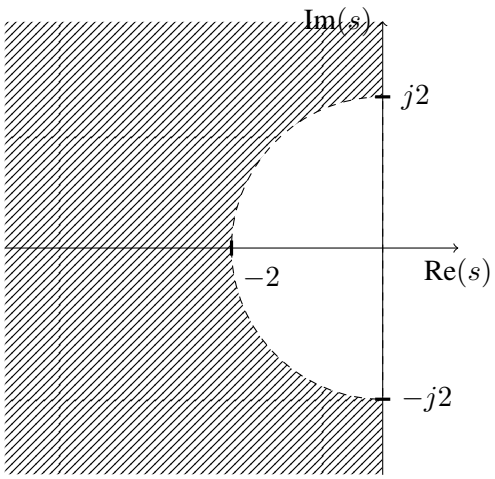
$$T(s) = \frac{\omega_n^2}{s^2 + 2\zeta\omega_n s + \omega_n^2}.$$

For each of the following plots, if the poles lie within the shaded region, what guarantees can be given in terms of step response rise time, settling time, and/or percent overshoot? (That is, we are looking for inequalities such as $t_r < 3$ s.)

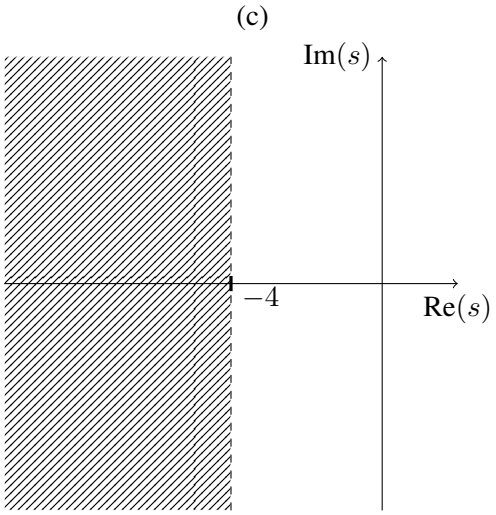
(a)



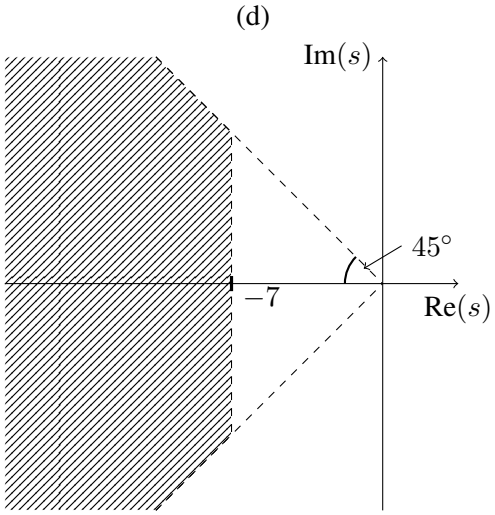
(b)



(c)

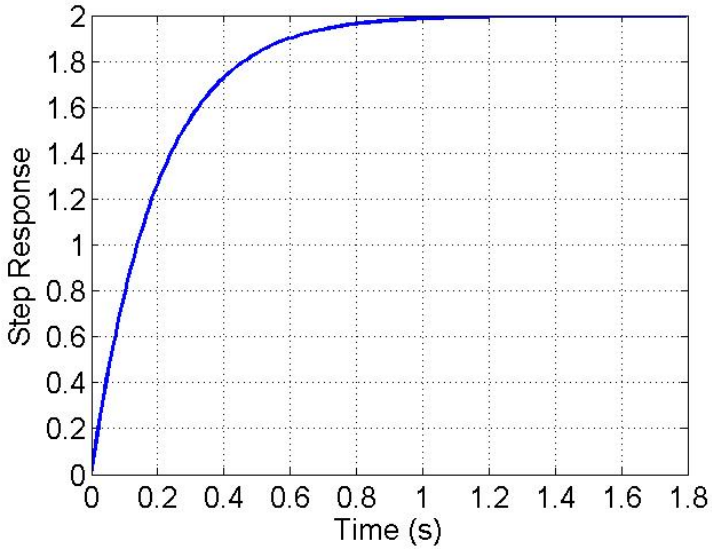


(d)



5. Quiz Question Friday: A client provides you with a transfer function and unit step response plot for a system you are analyzing.

$$G(s) = \frac{100}{s + 50}$$



(a) Based on the client-provided transfer function $G(s)$, estimate the rise time and 1% settling time for the step response. *Only one significant digit is needed; feel free to use rounding approximations such as* $1.4 \approx 1$ *and* $1.6 \approx 2$.

(b) Estimate the rise time and 1% settling time from the plot.

(c) Did the client provide the plot that corresponds to the transfer function? For full credit, briefly explain why or why not within the space provided.

6. Quiz Question Monday: For the following systems, estimate the rise time, settling time, and percent overshoot for a step reference input

   (a) $G(s) = \frac{6}{s+15}$

   (b) $G(s) = \frac{16}{s^2+3s+25}$

Solutions:

1. $\frac{(R_1+R_2)\rho g}{R_1 R_2 A} > 0.46$
2. $K_2 = 0.11$ and $K_1 = 0.83$
3. $\omega_n > 4.4$, $\zeta\omega_n > 2.3$, $\zeta > .46$

4. (a) $t_s > 4.6$s, $t_r > 2.2$s, $\%OS < 16\%$
   (b) $t_r < 1.1$s
   (c) $t_s < 1.15$s, $tr < 0.55$s
   (d) $t_s < 0.66$s, $tr < 0.314$s, $\%OS < 5\%$.