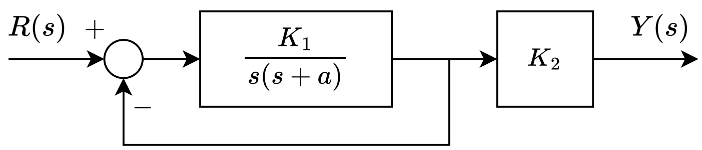
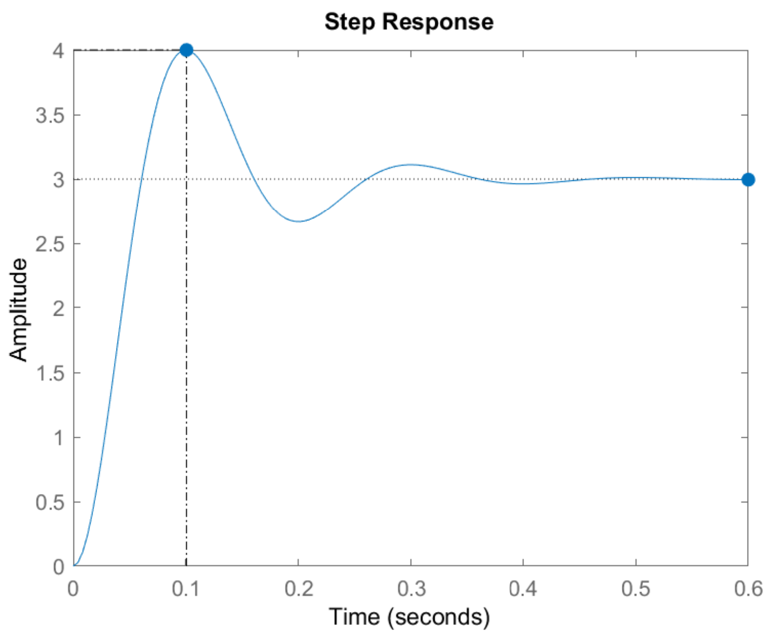
EE160 Homework 2

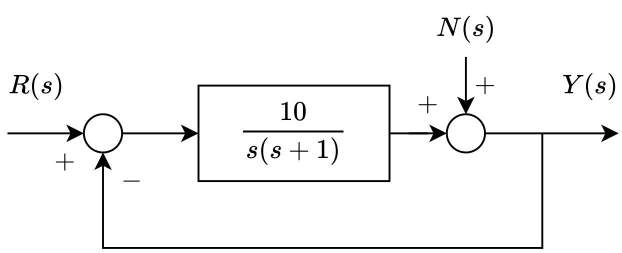
Deadline: 2022-10-23, 23:59:59, Submit your homework on Blackboard

1. Consider the following 2nd-order system and its **unit step response**, some performance indices have been given in the figure, determine K_1, K_2 and a, respectively. **(9')**





2. Consider the following 2nd-order system.



(a) When $r(t) = 1(t)$ (unit step signal), $n(t) = t$, calculate the steady-state error of the system. **(6')**

(b) When $r(t) = 1(t)$ (unit step signal), $n(t) = 0$, calculate peak time T_p, settling time T_s and the percent overshoot $P.O.$ of the step response. **(7')**

3. Consider the **unity feedback** third-order system with **open-loop** transfer function $G(s) = \frac{1}{s(0.1s+1)(0.5s+1)}$.

   (a) Calculate the **poles** of the **closed-loop** transfer function. **(5')**

   (b) Determine whether the response of the third-order system can be approximated by the dominant roots of the second-order system. If so, plot the **unit step response** of the **approximated second-order** system and the **original third-order** system on the **same** figure; if not, give your reasons. **(7')**

4. Consider two **unity feedback** systems, necessary information of the **open-loop** transfer function has been given in the table.

system	type number	zeros	poles	high frequency gain
i.	1	-1	$-4, -1 \pm j$	7
ii.	2	$-\frac{1}{2}, -\frac{1}{4}$	$-1 \pm 3j$	10

   (a) Determine the **open-loop** transfer function $G(s)$ of each system. **(4')**

   (b) Calculate the position error constant K_p, velocity error constant K_v and acceleration error constant K_a of each system, respectively. **(6')**

   (c) Based on the error constants derived in (b), give the steady-state error e_{ss} when the input signal $r(t) = 1(t)$ (unit step signal), $r(t) = t$ and $r(t) = t^2$ of each system, respectively. **(6')**

5. Using the Routh-Hurwitz criterion, determine if the system with the following characteristic equation is stable.**(10')**

   (a) $s^4 + 2s^3 + s^2 + 2s + 1 = 0$

   (b) $s^5 + 8s^4 + 15s^3 + 36s^2 + 42s + 11 = 0$

6. Determine the range of K for a stable system **(10')**

   (a) a system with a characteristic equation $s^3 + Ks^2 + (1+K)s + 6 = 0$

   (b) A unit negative feedback system with a open-loop transfer function

$$G(s) = \frac{K}{(s+2)(s+3)(s+5)}$$

7. Consider the feedback control system shown in the following Figure. The controller and model transfer functions are given by

$$G_c(s) = K \quad \text{and} \quad G(s) = \frac{s+40}{s(s+10)}$$

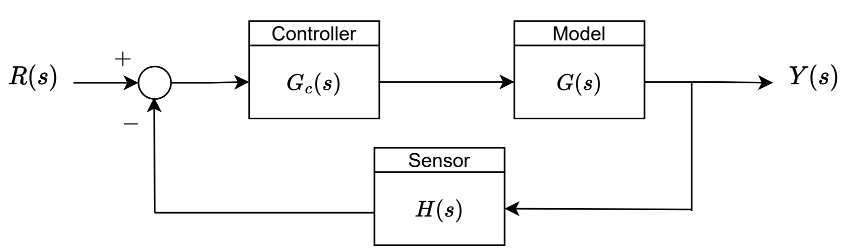
and the sensor transfer function is

$$H(s) = \frac{1}{s+20}$$

.**(15')**

   (a) Determine the limiting value of gain K for a stable system.

   (b) Let $K = 3$, determine whether the relative stability of the system is smaller than -1 ($\sigma < -1$).



8. Consider a spacecraft attitude control problem. The control system structure is shown below. Suppose we only consider the pitch-axis rotation of the spacecraft, which has a plant transfer function

$$G(s) = \frac{1}{Is^2} + \frac{L/I}{s^2 + 2\zeta\omega s + \omega^2}$$

where $I = 77,076kg/m^2$ is the spacecraft pitch inertia, $L = -1.387$ the telescope structure gain in the pitch axis, $\omega = 14.068$rad/s the structure natural frequency, and ζ the passive damping ratio assumed as 0.005. A proportional plus derivative controller is used in the system, where

$$G_c(s) = K_p + K_D s$$

and where $K_p > 0$ and $K_D > 0$. Please give a selection of K_p and K_d via trial and error to stabilize the system and proof the stability. **(15')**