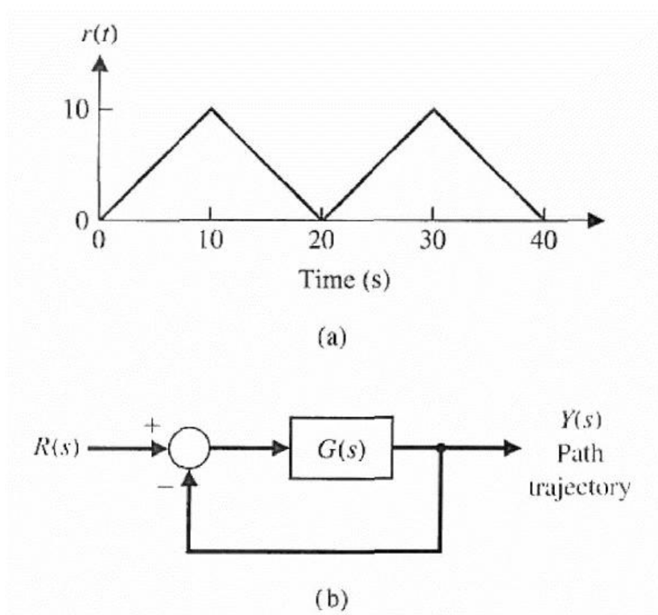
ME 5200/6200 and ECE 5615/6615 Classical Control **Fall 2024**

Homework 06 **Due Thursday, Oct. 24 at the beginning of class**

Do the following problems and show all your work for full credit. Note: not all problems will be graded, but you must complete all problems to get full credit.

Problem 1

Consider the following reference input and block diagram below:



Let the transfer function for the system be:

$$G(s) = \frac{75(s+1)}{s(s+5)(s+25)}$$

(a) Use Matlab to plot the time response of the output of the closed-loop system.
(b) Use Matlab to make a plot of the tracking error as a function of time.
(c) From the error plot, what is the steady state error when the input r(t) is shown above.

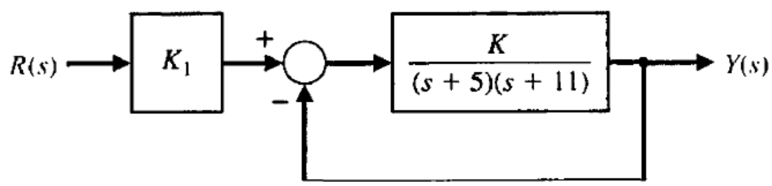
Make sure to submit a PDF print out of your Matlab code (m-file or Simulink diagram).

Problem 2

For the closed-loop system below,

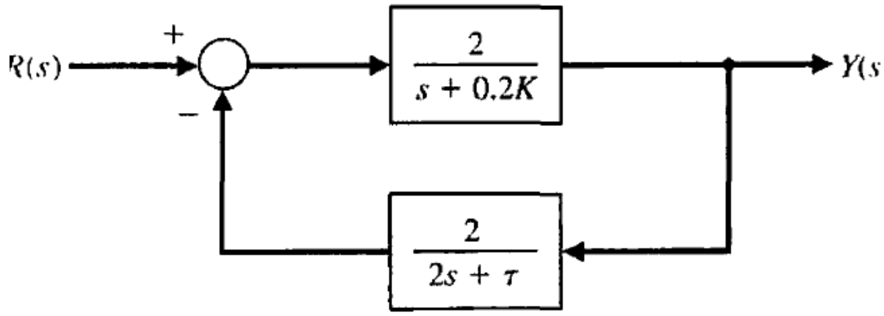
(a) Determine the steady-state error for a unit step input in terms of K and K_1, where $E(s) = R(s) - Y(s)$.

(b) Select K_1 so that the steady-state error is zero.



Problem 3

Consider the system below:

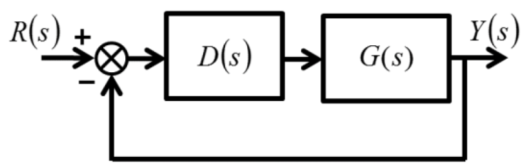


$$G_c(s)G(s) = \frac{2}{s + 0.2K} \quad \text{and} \quad H(s) = \frac{2}{2s + \tau}.$$

If $\tau = 2.43$, determine the value of K such that the steady-state error of the closed-loop system response to a unit step input, $R(s) = 1/s$, is zero.

Problem 4

Consider the closed-loop block diagram shown below. Let $G(s) = \frac{1}{(s+3)(s+4)}$. For each controller given below, find the steady-state error for: (i) a unit step input, (ii) a unit ramp input, and (iii) a unit parabolic input. State the system type and calculate the appropriate error constant for each of the five controllers. Assume, in each case, that the closed-loop system is stable.



(a) $D(s) = 2$ (a P controller)

(b) $D(s) = \frac{2(s+5)}{s}$ (a PI controller)

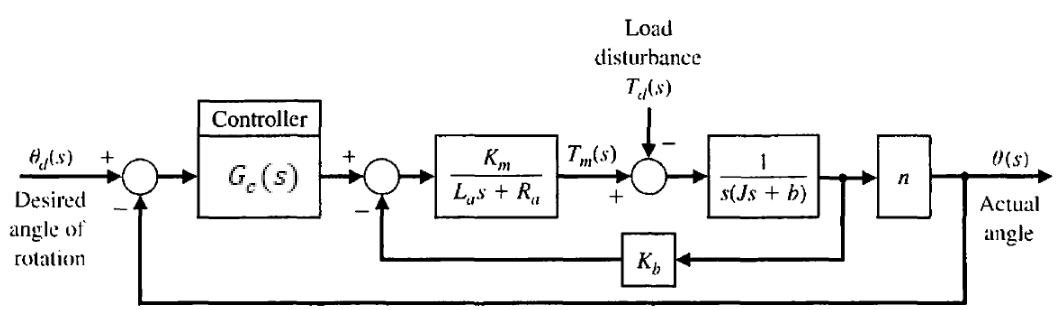
(c) $D(s) = 2(s+5)$ (a PD controller)

(d) $D(s) = \frac{2(s+5)(s+1)}{s(\tau s+1)}$, $\tau = \frac{1}{30}$ (a PID controller with a low-pass filter)

(e) $D(s) = \frac{2(s+5)(s+1)}{s^2}$ (a PID controller with a second integrator)

Problem 5

A robot arm has a shoulder joint where the model of the joint is given by the block diagram shown below. The joint uses a DC motor with armature control and has gears on the output shaft, so n is a constant. In the block diagram, there is a load disturbance $T_d(s)$ which represents the effect of the load. The entire closed-loop system shown below has two inputs, one for the desired angle of rotation and the other is the load disturbance. For simplicity, assume that K_m, L_a, R_a, J, b, n, and K_b are all equal to 1.



(a) Determine the transfer function that relates the desired angle of rotation $\theta_d(s)$ to the actual angle $\theta(s)$. What is the system type for this case?

(b) Determine the transfer function that relates the load disturbance $T_d(s)$ to the actual angle $\theta(s)$. What is the system type for this case?

(c) Determine the steady-state error when the desired angle $\theta_d(s)$ is a ramp input with slope B and the controller is $G_c(s) = 1/s$ (integral control). You can assume the disturbance is zero.

(d) Suppose the desired angle is zero and the load disturbance is a step of magnitude D. Determine the steady-state error if $G_c(s) = K$ (proportional control).