EXAM 3

March 5, 2021

Do All Problems – Show All Work
This exam is open notes and open book.

You have 24 hours to complete all problems.

Student ID: ______________________________

Student Printed Name: ______________________________

Student Signature: ______________________________

Name: ______________________________________ ID: ____________________________

1.) (20 pts) Please consider a plant described by the transfer function:

$$G(s) = \frac{1}{s(s^3 + 5s^2 + 21s + 5)}$$

A standard proportional feedback controller is designed for this plant with a gain $K_p = 100$.

a) Is this closed-loop system stable? If not, how should K_p be chosen to make it stable?

b) Using the maximum stable K_p value in (a), please determine the steady-state error of the closed-loop system for a unit ramp reference. Can a smaller steady-state error be achieved with this controller?

Name: ______________________________________ ID: _____________________________

2.) (20 pts) A first-order system has a transfer function of $G(s) = \frac{2}{s+2}$ and is supposed to be controlled through a unity-feedback control system.

a. Design a **P-controller** with proportional gain of K_p. Then,
   1- determine the range of stable controller gain.
   2- What is the order of the control system (closed-loop TF)?
   3- Find the steady-state error of the system to a unit step input.

b. Design a **I-controller** with integral gain of K_i and
   1- determine the range of stable controller gain.
   2- What is the order of the control system (closed-loop TF)?
   3- Find the steady-state error of the system to a unit step input.

c. Comparing your results in (a-2) and (b-2), what do you conclude? Please explain your answer.

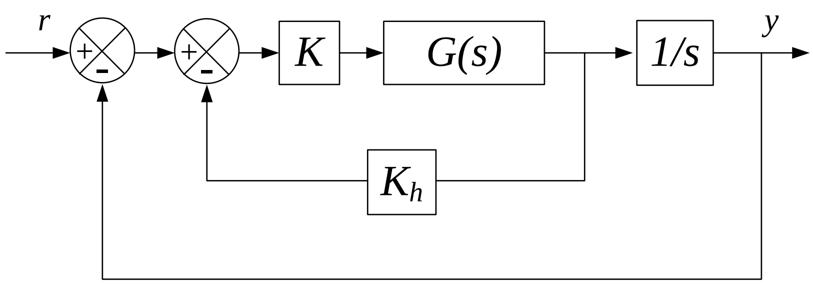
d. Comparing your results in (a-3) and (b-3), what do you conclude? Please explain your answer.

Name: ______________________________________ ID: _____________________________

3.) (20 pts) Please consider the feedback control system shown below where $G(s) = \frac{1}{s+2}$.

a) Determine the control coefficients K and K_h to achieve a peak overshoot of 0.25 (or 25%) and a peak time of 1 second.

b) Using the coefficients found in (a), calculate the exact rise time, and 2% settling time.



Name: ______________________________________ ID: ____________________________

4.) (40 pts) Please consider the mass-damper system shown below with mass $m = 2kg$ and damper coefficient $c = 8\ N.s/m$.

a) Derive the differential equation for this system (time domain).

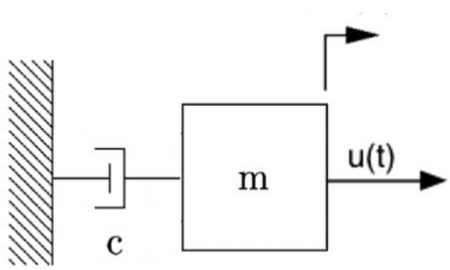
b) Derive the transfer function of the system (s-domain).

c) Using your control engineering insight, design three separate proportional unity-feedback control systems as follows such that each control system results in the same settling time of 2 seconds (using 2% criterion):

1. System #1: The first controller (K_{p1}) should result in an under-damped response.
2. System #2: The second controller (K_{p2}) should result in a critically damped response.
3. System #3: The Third controller (K_{p3}) should result in an over-damped response.

d) For each of the three control systems:

1. find poles of the closed-loop system and show them on the s-plane?
2. calculate steady-state error to a unit-step input.
3. calculate steady-state error to a unit-ramp input.
4. using MATLAB, plot the response to both unit-step and unit-ramp inputs.



Name: ______________________________________ ID: ____________________________

Extra Page