MACHAKOS UNIVERSITY

University Examinations for 2019/2020Academic Year

SCHOOL OF ENGINEERING AND TECHNOLOGY
DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

FOURTH YEAR SECOND SEMESTER EXAMINATION FOR

BACHELOR OF SCIENCE IN MECHANICAL ENGINEERING

EMM 416: CONTROL ENGINEERING I

DATE: 9/11/2020 **TIME: 8.30-10.30 AM**

INSTRUCTIONS

Answer Question One and Any Other Two Questions

Make your answers Exact and concise

QUESTION ONE (30 MARKS)

a) A second order system has an un-damped natural frequency of 100rad/s and a damping factor of 0.3. The value of the coefficient of the second time derivative is 5m. If the static sensitivity is 10, write down the response for a force excitation shown in Figure Q 1a) in terms of the *Duhamel's Integral* for the periods $0 < t < t_1, t_1 < t < t_2 \; and \; t > t_2$ (4 marks)

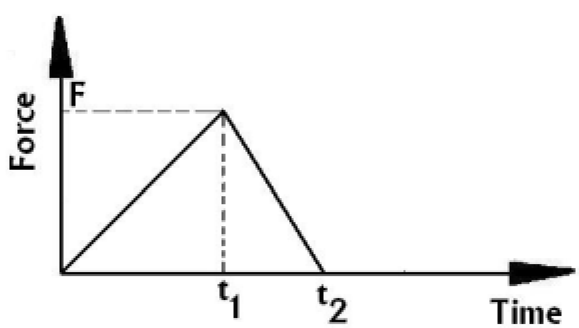


Figure Q 1a)

b) A second-order system has a damping factor of 0.3 (underdamped system) and an un-damped natural frequency of 10 rad/s. Keeping the damping factor the same, if the un-damped natural frequency is changed to 20 rad/s, locate the new poles of the system (5 marks)

c) Using *Ruoth-Hurwitz Stability Criterion*, determine the range of K for which the system described below is stable (3 marks)

$$G(s) = \frac{K}{s(s+2)(s+4)}; H(s) = 1$$

d) Determine the overall transfer function of the system shown in Figure Q 1 d) using Masons-Gain Formula (4 marks)

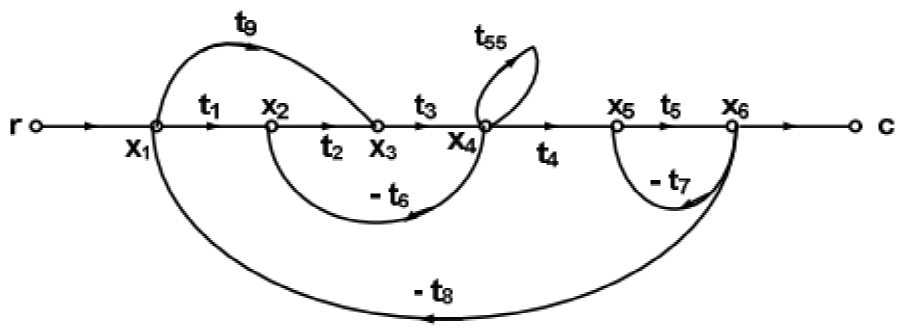


Figure Q 1 d)

e) An open loop transfer function for a control system is given by

$$G(s)H(s) = \frac{K}{s^2(s+1)}$$

Determine and draw the following

i. Root Locus for the feedback system (9 marks)

ii. Polar plot and compute gain margin, phase margin & absolute stability at gain K (5 marks)

QUESTION TWO (20 MARKS)

a) Figure Q 2 a) shows the second order time response specifications for a step-input for an underdamped scenario. Define and derive the expressions for the following time-domain specifications

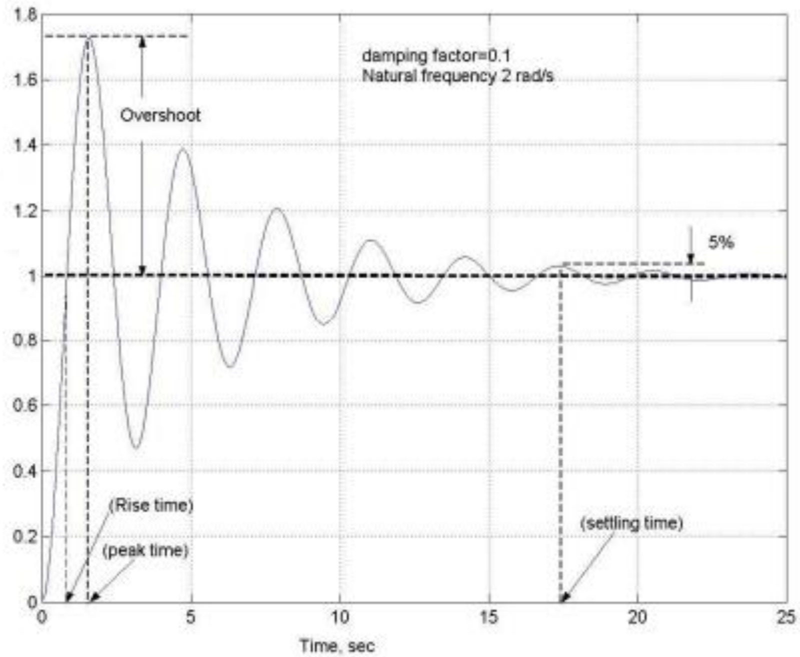
i. Delay time (1 mark)

ii. Rise time (1 mark)

iii. Peak time (2 marks)

iv. Peak overshoot (2 marks)

v. Settling time (1 mark)



$$y(t) = \frac{Kx_i}{m\omega_n^2}\left\{1 - \frac{e^{-\zeta\omega_n t}}{\sqrt{1-\zeta^2}}\sin(\omega_d t + \varphi)\right\}$$

$$\varphi = \tan^{-1}\frac{\sqrt{1-\zeta^2}}{\zeta}$$

Figure Q 2a)

b) Consider the system shown in Figure Q2bi). To improve the performance of the system a feedback is added to this system, which results in Figure Q 2bii).

i. Determine the natural frequency and the damping ratio for the system in Figure Q 2bi) (2 marks)

ii. Determine the value of K so that the damping ratio of the new system is 0.4 (4 marks)

iii. Using Routh-Hurwitz Criterion, determine the range of K for the stability of the system (2 marks)

iv. Compare the overshoot, rise time, peak time and settling time and the nominal value of the systems shown in Figures Q2bi) and 2bii) (5 marks)

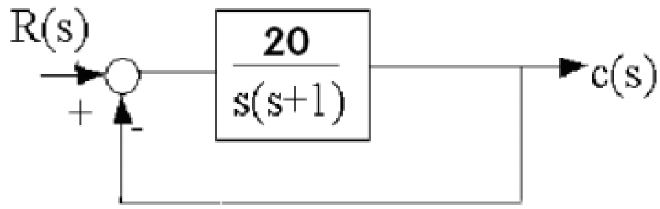


Figure Q 2bi)

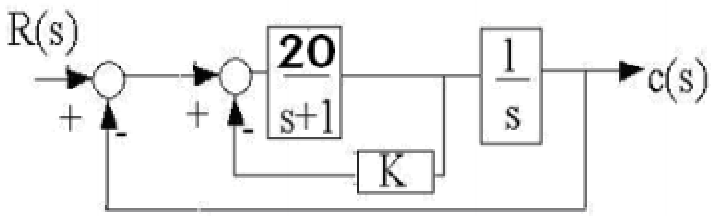


Figure Q 2bii)

QUESTION THREE (20MARKS)

a) Determine and draw the root-locus of the feedback system whose open loop transfer function is given by (8 marks)

$$G(s)H(s) = \frac{K(s^2 + 10s + 100)}{s^4 + 20s^3 + 100s^2 + 500s + 1500};\ H(s) = 1$$

b) Determine the following from the Root-Locus in a) above

i. Phase Margin and damping coefficient at which the system will be stable as well as have a maximum overshoot of 5% (2 marks)

ii. The gain margin at the point in bi) above (2 marks)

iii. The steady state error for a unit step excitation at the point in bi) above (2 marks)

c) Using Routh-Hurwitz Criterion, determine the range of K for the stability of the system a) above (6 marks)

QUESTION FOUR (20 MARKS)

a) A closed loop control system is represented by the Block Diagram shown in Figure Q 4a).

i. Derive the transfer function by Block Reduction Method (4 marks)

ii. Verify the results in 4ai) above using the Signal Flow Graph Approach (4 marks)

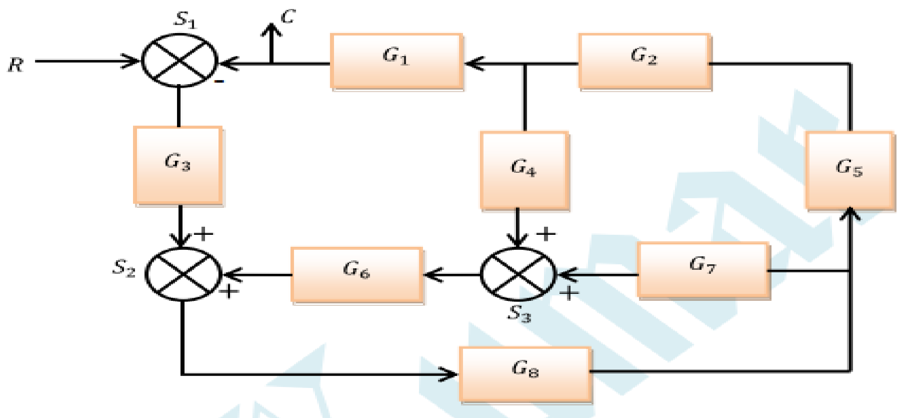


Figure Q4a)

b) A closed loop control system is represented by the Block Diagram shown in Figure Q 4 b).

i. Derive the transfer function by Block Reduction Method (4 marks)

ii. Verify the results in 4bi) above using the Signal Flow Graph Approach (4 marks)

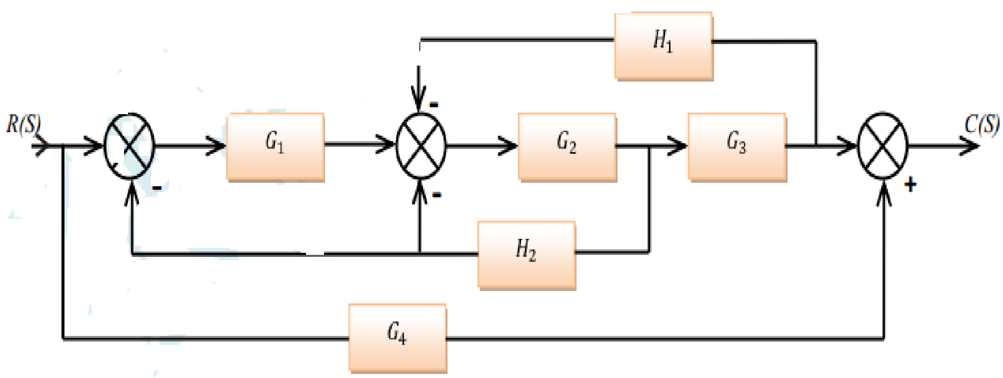


Figure Q4b)

c) Determine the restrictions on K for which the system represented by the SFG in Figure Q4c) is stable (4 marks)

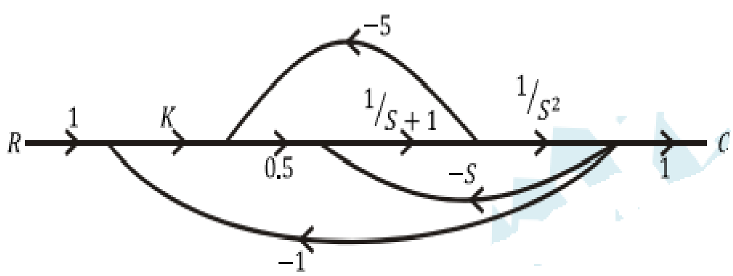


FIGURE Q4C)

QUESTION FIVE (20 MARKS)

a) Draw the Bode Magnitude and Phase Plot of the open loop transfer function given by

(9 marks)

$$G(s)H(s) = \frac{1}{s^4 + 5s^3 + 8s^2 + 6s}$$

Determine the gain margin and phase margin (2 marks)

b) Determine the closed-loop magnitude ratio and bandwidth of the feedback system whose forward transfer function is given by

$$G(s) = \frac{10}{s(s+2)(s+40)} \ and\ H(s) = 1$$

Using the following methods

i) Direct Computation (5 marks)

ii) M and N circles (4 marks)