MACHAKOS UNIVERSITY

University Examinations for 2021/2022

SCHOOL OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING

FIFTH YEAR SECOND SEMESTER EXAMINATION FOR

BACHELOR OF SCIENCE (ELECTRICAL AND ELECTRONICS ENGINEERING)

EMM 416: CONTROL ENGINEERING I

DATE: 17/12/2021 **TIME: 11.00-1.00 PM**

Instructions

- *This paper consists of Five Questions*
- *Question **One is Compulsory***
- *Attempt Any other Two Questions*
- *Make your answers Exact and concise*

QUESTION ONE (COMPULSORY) (30 MARKS)

a) Explain the differences between Closed Loop and Open Loop Systems in Table Form. Give Examples in each case. (5 marks)

b) Figure Q 1b) shows a resistance thermometer and valve connected together. The input is temperature and the output is the valve position. Determine an expression of the unit step response when there are zero initial conditions (8 marks)

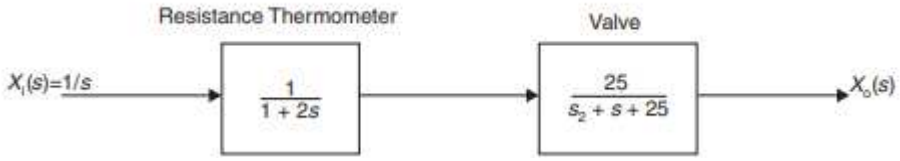


Figure Q 1b)

c) The open loop transfer function of a control system is given by the expression

$$G(s)H(s) = \frac{K\,(S+0.5)(S+2)}{S^3(S+6)(S+8)}$$

Determine the range of the gain constant, K, for stability using the *Routh-Hurwitz Criteria* (5 marks)

d) Determine and Sketch the Root Locus defined by each of the following Characteristic Equation

$$S(S+4)(S^2+4S+20)+K=0$$ (6 marks)

e) Figure Q 1e) is the block diagram of an engine-speed control system. The speed is measured by a set of fly weights. Derive and draw a Signal Flow Graph for the System (6 marks)

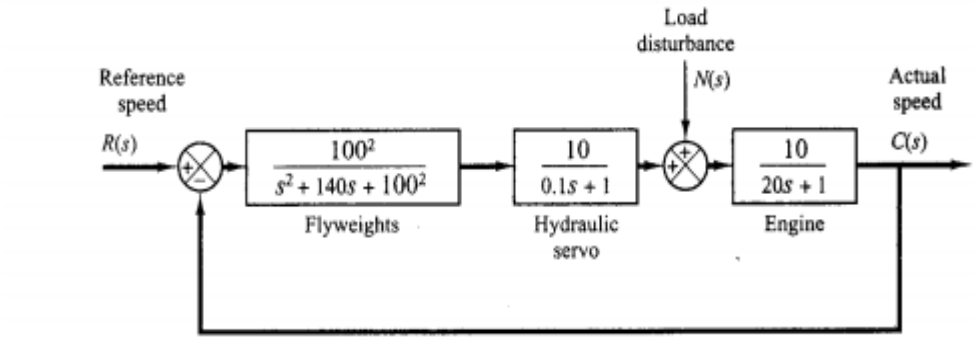


Figure Q 1 e)

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

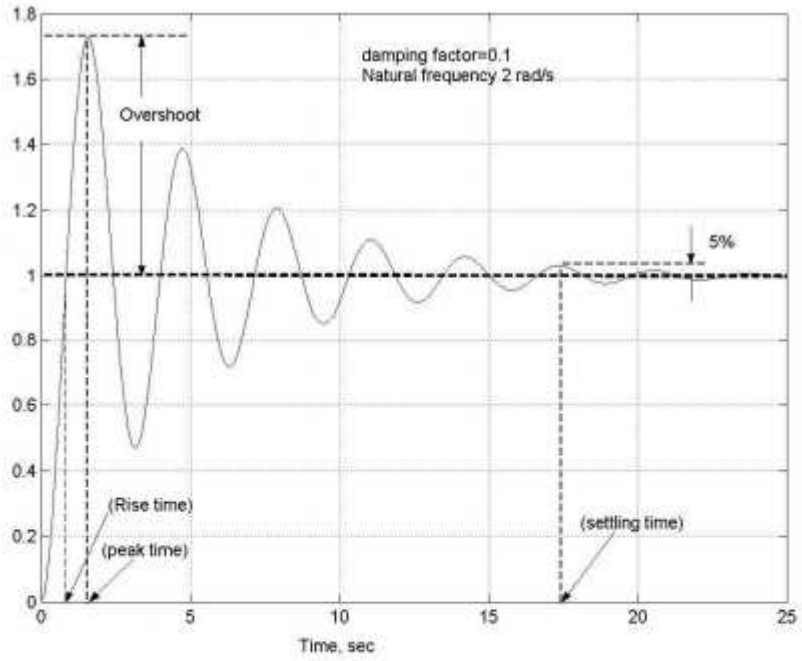
i. Delay time (1.5 marks)

ii. Rise time (1.5 marks)

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, system 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) (3 marks)

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

iii) Determine and tabulate the overshoot, rise time, peak time and settling time and the nominal value of the systems shown in Figures Q2bi) and 2bii) (5 marks)

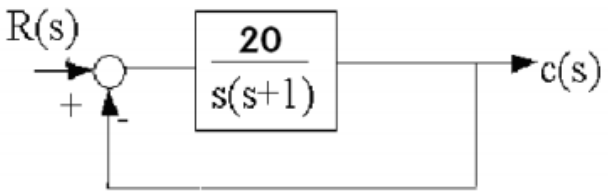


Figure Q 2bi)

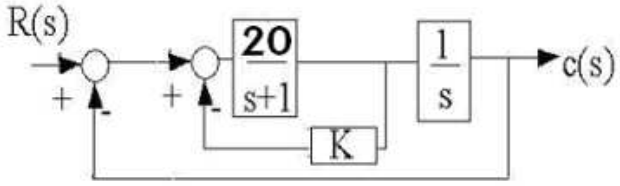


Figure Q 2bii)

QUESTION THREE (20 MARKS)

a) Define the term *Control System Stability* as broadly as possible (3 marks)

b) Discuss the *Ruoth-Hurwitz Criteria for* system stability (3 marks)

c) The open loop system transfer function of a unity feedback is given by the expression

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

Determine the value of K for which the system is just stable (5 marks)

d) The open loop system transfer function of a unity feedback is given by the expression

$$G(s) = \frac{K}{(S+2)(S+4)(S^2+6S+25)}$$

Determine the value of K which will cause sustained oscillations in the closed loop system, hence the corresponding oscillation frequency (4 marks)

e) Determine whether the control system defined by the Characteristic Equation given below is stable (4 marks)

$$S^4 + 20KS^3 + 5S^2 + 10S + 15 = 0$$

QUESTION FOUR (20 MARKS)

a) Explain the following Concepts as used in Control System Analysis

i. Transfer Function

ii. Mason's Gain Theorem

iii. Closed Loop System (4 marks)

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

i. Derive the Transfer Function by *Block Reduction Method*. Explain the Rules used clearly (5 marks)

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

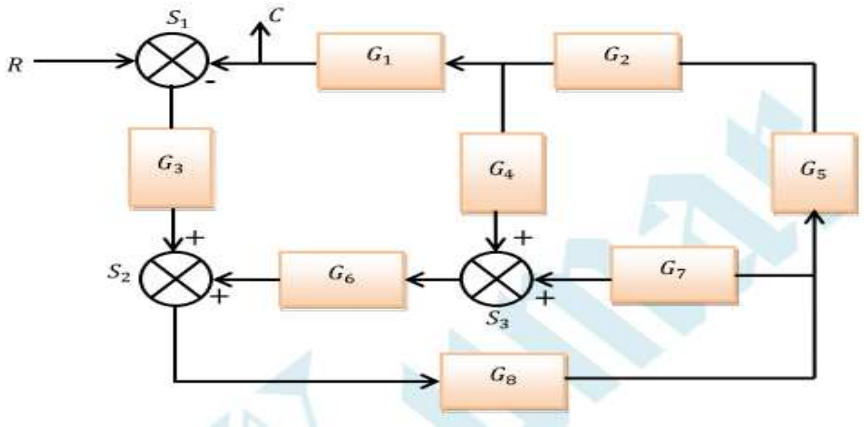


Figure Q4b)

c) For the system shown in Figure Q 4 c), determine the Closed Loop Transfer Function (4 marks)

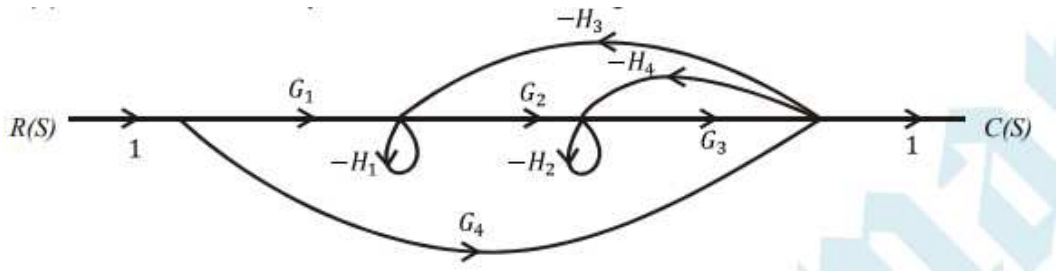


Figure Q 4c)

d) Explain the Three weaknesses of using Transfer function in Control System Analysis (3 marks)

QUESTION FIVE (20 MARKS)

a) 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 Root Locus for the feedback system (6 marks)

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

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

c) Determine the following from the Root-Locus in b) 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 (1 mark)

iii. The Position and steady state error for a unit step excitation at the point in bi) above. (3 marks)