MACHAKOS UNIVERSITY

University Examinations for 2022/2023 Academic Year

SCHOOL OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING

THIRD/FOURTH YEAR …… SEMESTER EXAMINATION FOR

BACHELOR OF SCIENCE (MECHANICAL ENGINEERING)

EMM 416: CONTROL ENGINEERING I

DATE: **TIME:**

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) (30MARKS)

a) Define Transfer Function of a Control System (1 mark)

b) Discuss the following Techniques of obtaining the Transfer Functions of closed loop systems

i) Marson's Gain Formula (MSG) (2 marks)

ii) Use of Block Reduction Algebra (5 marks)

c) For the control system defined by the equations given below,

$$x_1 = t_{01}x_0$$
$$x_2 = t_{12}x_1 + t_{32}x_3 + t_{42}x_4$$
$$x_3 = t_{03}x_0 + t_{13}x_1 + t_{23}x_2$$
$$x_4 = t_{04}x_0 + t_{34}x_3 + t_{54}x_5$$
$$x_5 = t_{15}x_1 + t_{45}x_4 + t_{65}x_6$$
$$x_6 = t_{06}x_0 + t_{76}x_7 + t_{56}x_5$$
$$x_7 = t_{67}x_6 + t_{77}x_7$$
$$x_8 = t_{78}x_7$$

i) Construct the Signal Flow Graph (2 marks)

ii) Determine the Transfer Function (6 marks)

d) For Figure Q 1d), compute the Transfer Function by Block Reduction (5 marks)

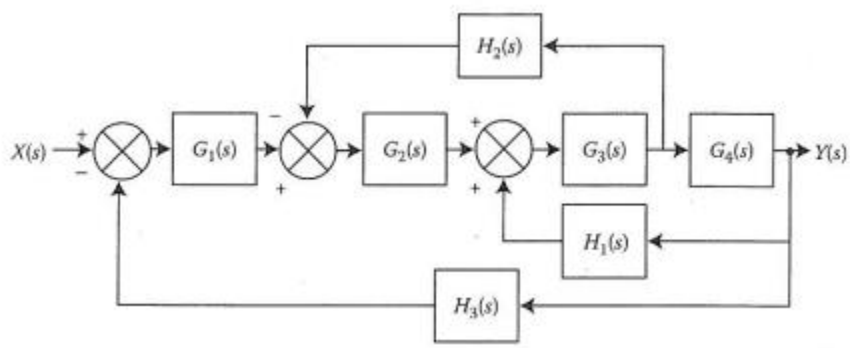

Figure Q 1d)

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 (4marks)

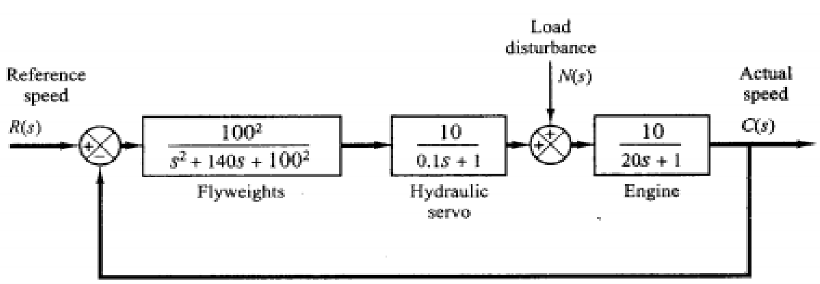

Figure Q 1 e)

f) Determine the restrictions on K for which the system represented by the SFG in Figure Q1f) is stable (5 marks)

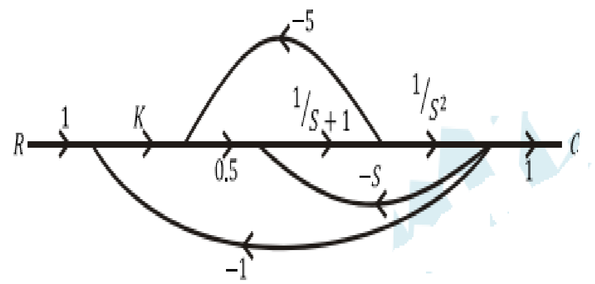

Figure Q1f)

QUESTION TWO (20 MARKS)

a) Beginning from a diagram, derive the general expression of the Steady State Error for a closed loop system hence show that it depends on the type and magnitude of the input and the open loop transfer function. (5 marks)

b) The various inputs to a Control System are given in Table 2. For Step, Ramp and Parabolic inputs of magnitude A, prove the parameters shown in Table Q 2 (6 marks)

Table Q 2

Error Constant	Equation	Steady-state error (e_{ss})
Position Error Constant (K_P)	$K_P = \lim_{s\to 0} G(s)H(s)$	$e_{ss} = \frac{A}{1+K_P}$
Velocity Error Constant (K_V)	$K_V = \lim_{s\to 0} sG(s)H(s)$	$e_{ss} = \frac{A}{K_V}$
Acceleration Error Constant (K_A)	$K_A = \lim_{s\to 0} s^2G(s)H(s)$	$e_{ss} = \frac{A}{K_A}$

Table 2

No.	Function	Time-domain $x(t) = \mathcal{L}^{-1}\{X(s)\}$	Laplace domain $X(s) = \mathcal{L}\{x(t)\}$
1	Delay	$\delta(t-\tau)$	$e^{-\tau s}$
2	Unit impulse	$\delta(t)$	1
3	Unit step	$u(t)$	$\frac{1}{s}$
4	Ramp	t	$\frac{1}{s^2}$
5	Exponential decay	$e^{-\alpha t}$	$\frac{1}{s+\alpha}$
6	Exponential approach	$(1-e^{-\alpha t})$	$\frac{\alpha}{s(s+\alpha)}$
7	Sine	$\sin \omega t$	$\frac{\omega}{s^2+\omega^2}$
8	Cosine	$\cos \omega t$	$\frac{s}{s^2+\omega^2}$
9	Hyperbolic sine	$\sinh \alpha t$	$\frac{\alpha}{s^2-\alpha^2}$
10	Hyperbolic cosine	$\cosh \alpha t$	$\frac{s}{s^2-\alpha^2}$
11	Exponentially decaying sine wave	$e^{-\alpha t}\sin \omega t$	$\frac{\omega}{(s+\alpha)^2+\omega^2}$
12	Exponentially decaying cosine wave	$e^{-\alpha t}\cos \omega t$	$\frac{s+\alpha}{(s+\alpha)^2+\omega^2}$

c) Figure Q 2c) shows a resistance thermometer and valve connected together. The input is temperature and the output is the valve position. Determine

i) An expression of the unit step response when there are zero initial conditions. Apply Table 2 (7 marks)

ii) Steady State Error for the System (2 marks)

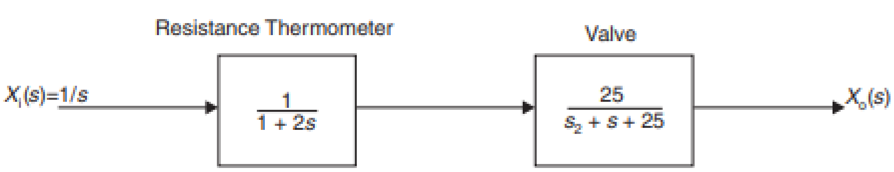

Figure Q 2c)

QUESTION THREE (20MARKS)

a) Discuss the *Ruoth-Hurwitz Criteria for* system stability (4 marks)

b) Investigate whether the Control System defined the Characteristic Equation given below is stable (4 marks)

$$S^7 + 9S^6 + 24S^5 + 24S^4 + 24S^3 + 24S^2 + 23S + 15 = 0$$

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 (4 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) A feedback system has open-loop transfer function given by

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

Determine the maximum value of 'K' for stability of the closed-loop system (4 marks)

QUESTION FOUR (20MARKS)

a) Determine and Draw the Root Locus of the feedback system whose open-loop transfer function is given by (6 marks)

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

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

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

Determine and draw the Root Locus for the feedback system (6 marks)

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

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

QUESTION FIVE (20MARKS)

An open-loop transfer function is defined by the relation

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

a) For $K = 1$, draw the Bode Magnitude and Phase Plot and determine the gain margin, phase margin and absolute stability (8 marks)

b) Draw the Polar Plot (4 marks)

c) Using Nyquist Criteria, determine the stability of the system in feedback mode (6 marks)