MACHAKOS UNIVERSITY

University Examinations for 2023/2024 Academic Year

SCHOOL OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING

FOUTH YEAR FIRST SEMESTER EXAMINATION FOR

BACHELOR OF SCIENCE (MECHANICAL ENGINEERING)

EMM416: 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 the following for a Control System (6marks)

i) Laplace Transform

ii) Inverse Laplace Transform

iii) Unit Step Response

iv) Damping Ratio

v) Natural Frequency

vi) Steady State Error

b) An elastic sensor for Conveyor Belt consists of a spring $Kx(t)$, a damper $C\frac{dx(t)}{dt}$ and a mass $m\left(\frac{dx(t)}{dt}\right)^2$. In this case, $x(t)$ is the displacement of the system due to the force $F(t)$ applied on the mass. Derive the expression of the displacement $x(t)$ when a unit step force is applied. The expression must be in terms of the damping ratio and the undamped natural frequency (8marks)

c) From the first principles, determine the output resistance expression, R(t) of a Resistance Thermometer when a sinusoidal input temperature, $T(t) = T\sin\omega t$,is applied when the system transfer function is given by

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

All symbols carry the usual meaning (8 marks)

d) Figure Q 1d) shows a resistance thermometer in 1c) above and a 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 (7 marks)

ii) Steady State Error for the System (1mark)

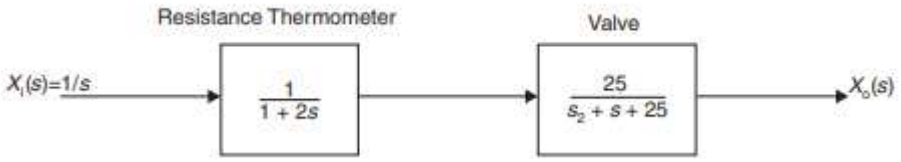

Figure Q 1d)

QUESTION TWO (20 MARKS)

a) Explain the differences between Closed Loop and Open Loop Systems in Table Form. Give Examples in each case (6marks)

An armature-controlled DC motor can be represented by Figure Q 2b&c). Study it carefully and answer parts b) and c)

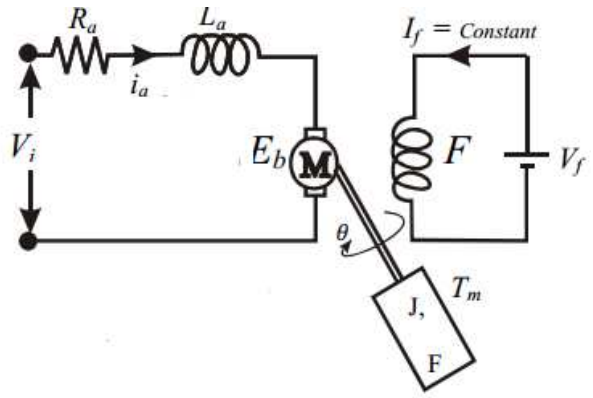

Figure 2 b&c)

b) Derive the Transfer Function of the System (4 marks)

c) By block representation, show that this is a closed Negative Feedback System (3 marks)

The equivalent circuit of a Field Controlled DC Motor is as shown in Figure Q 2d&e). Study it carefully and answer parts d) and e)

d) Show that this control system is an *Open Loop Third Order* Type (4 marks)

e) Draw the Block Representation in Question 2d) above (3 marks)

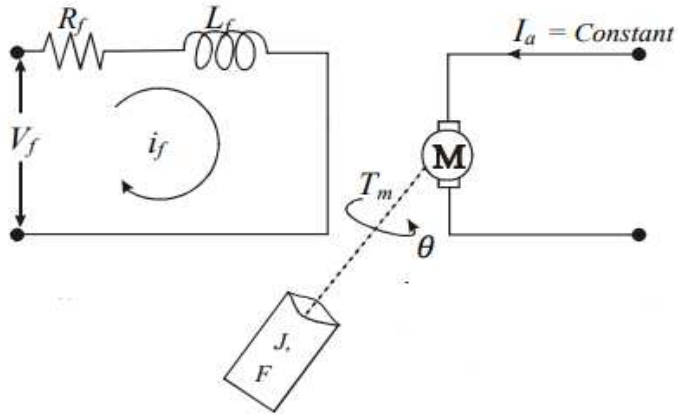

Figure Q 2 d&e)

QUESTION THREE (20MARKS)

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

i) Use of Block Reduction Algebra (5 marks)

ii) Marson's Gain Formula (MSG) (3 marks)

b) A closed loop control system is represented by the Block Diagram shown in Figure Q 3b). Derive the transfer function by Block Reduction Method (6 marks)

c) Verify the results in Question 3b) above using the Signal Flow Graph Approach (6 marks)

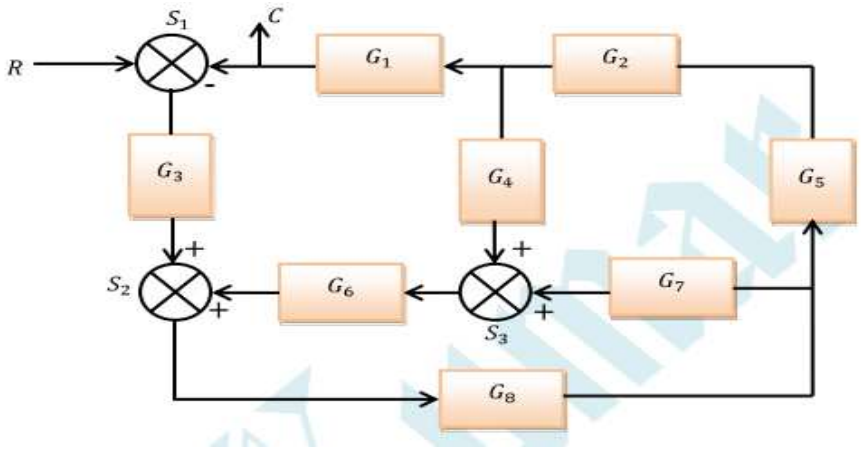

Figure Q 3b)

QUESTION FOUR (20MARKS)

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

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

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

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

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

(8marks)

b) Draw the Polar Plot

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