MACHAKOS UNIVERSITY

University Examinations for 2023/2024 Academic Year

SCHOOL OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING

THIRD YEAR FIRST SEMESTER EXAMINATION FOR

BACHELOR OF SCIENCE (ELECTRICAL AND ELECTRONICS ENGINEERING)

EEE 310: CONTROL SYSTEMS I

DATE: **TIME:**

INSTRUCTIONS

Answer any other TWO questions

QUESTION ONE IS COMPULSORY (30 MARKS)

a) State any TWO advantages of open loop systems. (2 marks)

b) For the circuit in fig.1, determine the steady state error to a unit step input. (5 marks)

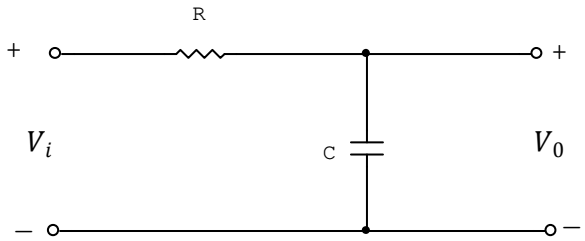

Fig.1

c) With refernce to signal flow graph, explain the following terms:

i. A source
ii. A sink
iii. Non touching loops
iv. A path. (6 marks)

d) A second order system is represented by the differential equation:

$$\frac{d^2\theta_o}{dt^2} + 2\frac{d\theta_o}{dt} + 5\theta_o = 5\theta_i$$

Where $\theta_o is\ the\ output\ and\ \theta_i\ is\ the\ input.$ Determine for a unit step input:

i. Output time response

ii. Peak time
iii. Settling time for a tolerance of $\pm 5\%$ (8 marks)

e) The Open loop frequency response of a control system is given by:

ω(rad/sec)	0.1	0.5	1	1.5	2.5	3.5	4.5	5.5
GH(dB)	34	19.7	12.6	7.8	0.7	-4.72	-9	-12.7
Phase lag(°)	94	109	127	140	160	174	184	192

Use Nichols chart to determine:
(i) Gain margin
(ii) Phase margin
(iii) Whether the system is stable or unstable. (9 marks)

QUESTION TWO (20 MARKS)

a) Briefly desribe a physical model. (2 marks)

b) Explain the Routh Stability creterion. (3 marks)

c) Two of the standard test signals are unit ramp and sinusoidal signal. For the two signals:
i. Give their description
ii. Graphical representation
iii. Time domain mathematical representation
iv. S-domain mathematical representation. (8 marks)

d) In the speed control system in fig. 2, the generator field time constant is negligible. It is driven at constant speed giving generated voltage of Kg volts/field ampere. The motor is separately excited so as to have a counter emf of Kb volts per rads/sec. It produces a torque of KT newton-m/ampere. The motor and its load have a combined moment of inertia Jkg-m2 and negligible friction. The tachometer has Kt volts per rads/sec and the amplifier gain is KA Amp/volt. Draw the block diagram of this system and there from determine the transfer function ω(s)/Ei(s), where ω is the load speed.

(7 marks)

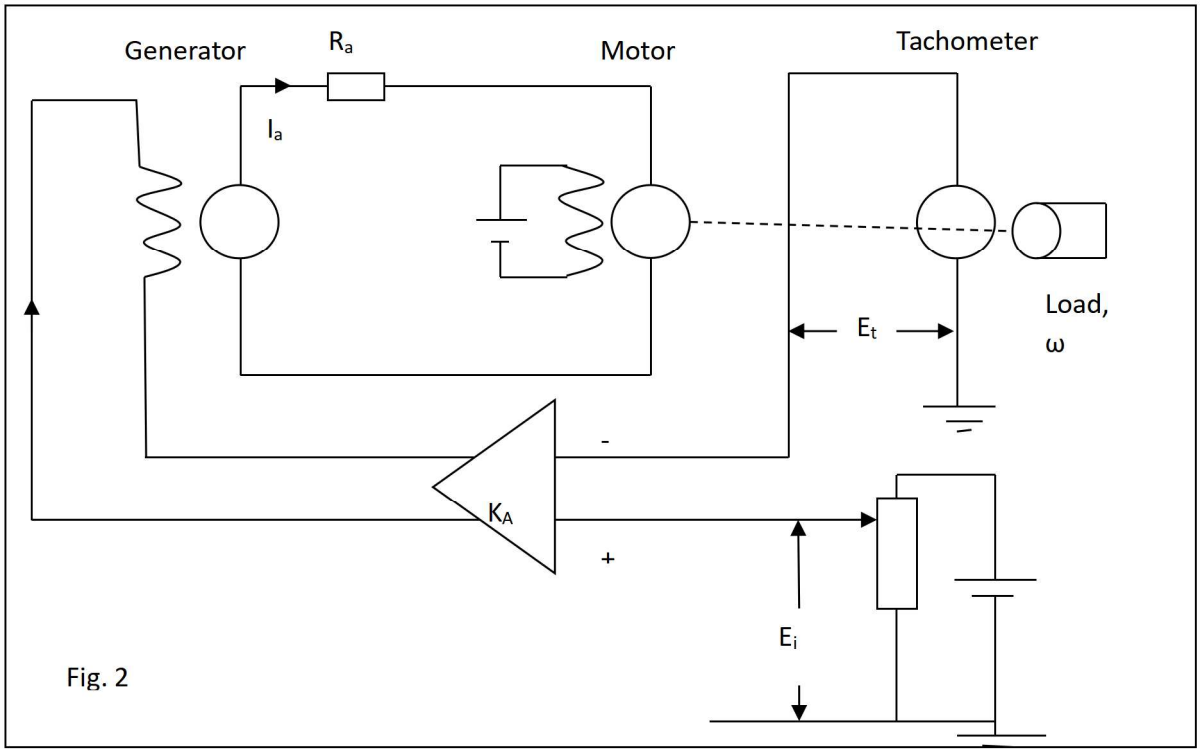

Fig. 2

QUESTION THREE (20 MARKS)

a) Explain the Nyquist stability creterion. (2 marks)

b) Briefly explain what is meant by analogous systems. (2 marks)

c) A new system was brought to CHAPO industries from a foreign country. The transfer function of the system is given by:

$$G(jw) = \frac{10}{jw(1 + 0.01jw)(1 + 0.1\text{jw})}$$

Using Bode plots:

i. Determine it phase margin
ii. Determine the gain margin
iii. Is the system stable or unstable. (8 marks)

d) For mechanical system shown in fig. 3, Torque(t) is the input signal and angular displacement θ is the output signal. Determine:

iv. Its differntial equation
v. Its transfer function
vi. If input signal is a step inpu, what is the output expression
vii. Sketch the response curve. (8 marks)

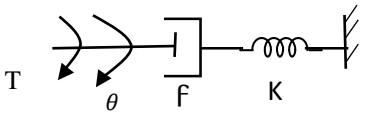

Fig.3

QUESTION FOUR (20 MARKS)

a) With aid of a diagram show the region occupied by poles on s-plane for a stable, unstable and limitedly stable systems. (4 marks)

b) For the electrical network shown in fig.4, derive the transfer function $V_{0(S)}/U_{i(S)}$. (6 marks)

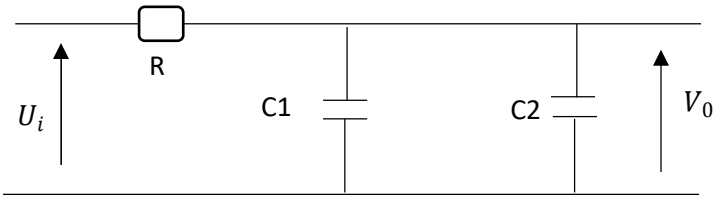

Fig. 4

c) Using Mason's gain formula, determine the transfer function of the signal flow graph in fig. 5. (10 marks)

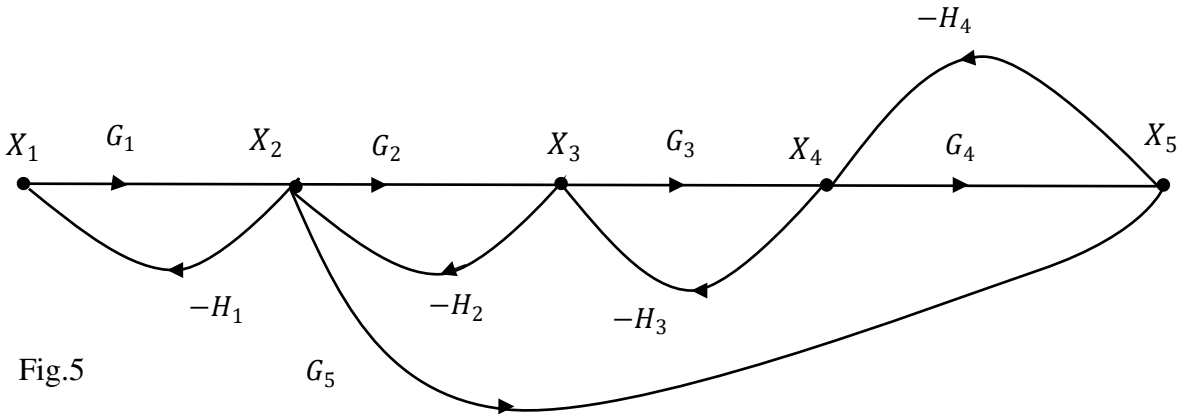

Fig.5

QUESTION FIVE (20 MARKS)

a) Explain the following terms with respect to response of an underdamped second order system, when subjected to unit step input:
   i. Delay time
   ii. Peak overshoot time. (4 marks)

b) For the translational mechanical system in fig. 6:
   i. Sketch it free body diagram
   ii. Determine the differential equations relating the different forces acting on the body.
   iii. Derive the transfer function $X_{(S)}/F_{(S)}$. (5 marks)

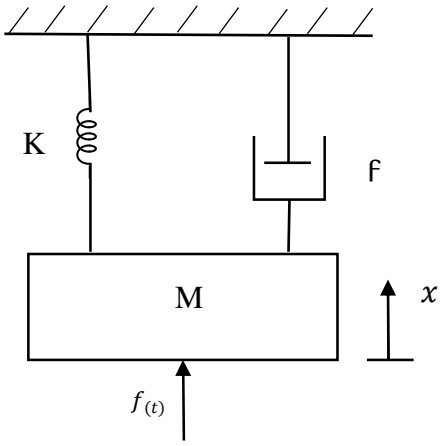

Fig.6

c) Using block diagram reduction techniques, determine transfer function of system whose transfer function is shown in fig. 7. (7 marks)

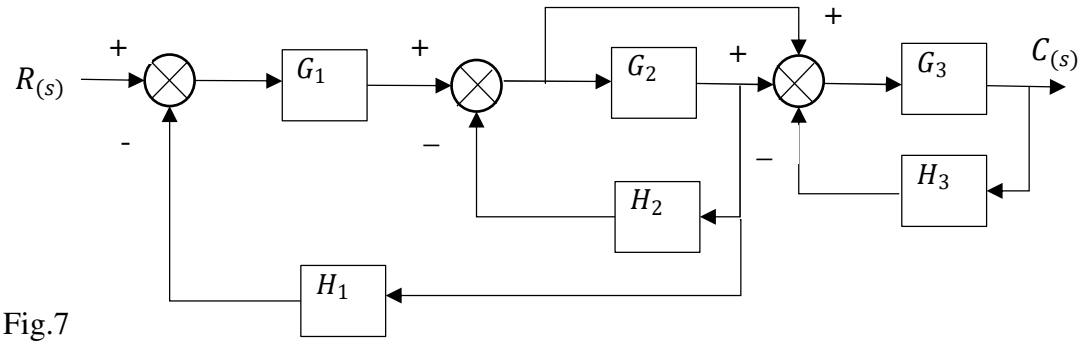

Fig.7

d) A system open loop transfer function is given by:

$$G_{(S)}H_{(S)} = \frac{100}{S(S+10)(S+5)}$$

Calculate:

i. Phase cross over frequency
ii. Gain margin (4 marks)