TECHNICAL UNIVERSITY OF MOMBASA

School of Engineering and Technology

Department of Mechanical and Automotive Engineering

UNIVERSITY EXAMINATION FOR:

Bachelor of Science in Mechanical Engineering

EMC 4428: CONTROL ENGINEERING

END OF SEMESTER EXAMINATION

SERIES: AUGUST 2024 EXAM

TIME: 2 HOURS

DATE: Pick DateSelect MonthPick Year

Instructions to Candidates

You should have the following for this examination

-Answer Booklet, examination pass and student ID

This paper consists of five Questions; Question ONE is compulsory. In addition, attempt any Other TWO Questions.

Do not write on the question paper.

Question ONE

(a) Distinguish between open and closed loop control schemes (2 marks)

(b) Explain the difference between regulator and servo-control problem in control system study (2 marks)

(c) Figure Q 1(c) represents a closed loop system with negative feedback. Derive expressions for:

i) The closed loop transfer function

ii) The error ratio

iii) The primary feedback transfer function

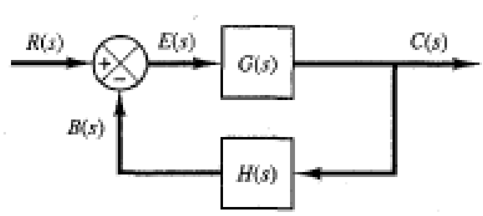


Figure Q1 (c) (6 marks)

(d) Obtain the closed-loop transfer function of Figure Q1 (d) by using Mason's rule. (8 marks)

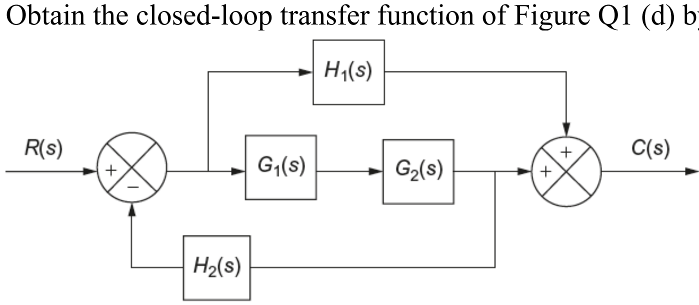


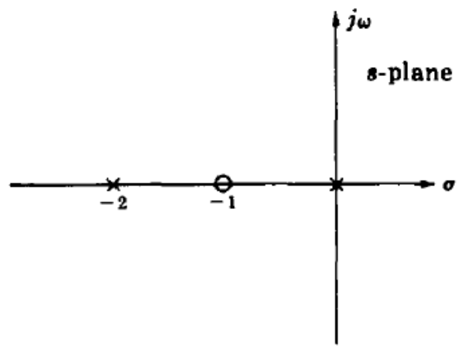
Figure Q1 (d)

(e) A negative feedback system with a forward gain of 2 and a feedback gain of 8 is subjected to an input of 5 V. Determine the output voltage of the system. (2 marks)

(f) Define Laplace transform and transfer function and comment upon their utility for the solution of control system problems (4 marks)

(g) Distinguish between poles and zeros of a transfer function (2 marks)

(h) Determine the transfer function of a system with a gain factor of 2 and a pole - zero map in the s-plane as shown in Figure, Q. 1(h) (4 marks)



Figure, Q. 1(h)

Question TWO

(a) State what is meant by system modeling (2 marks)

(b) A simple mass-spring-friction system is shown in Figure Q2 (b). Consider the force P to be the input and the displacement y of the mass M as the output of the system. Derive the expression for the transfer function

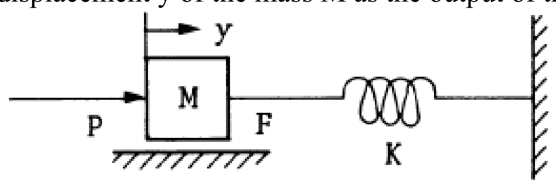


Figure Q2 (b) (3 marks)

(c) For an RLC circuit series network of Figure Q 2(c), the output is taken across the capacitor. Show that the transfer function is given as

$G(s)=\frac{\omega_n^2}{s^2+2\zeta\omega_n s+\omega_n^2}$ where the undamped natural frequency $\omega_n=\frac{1}{\sqrt{LC}}$ and the damping coefficient

$\zeta=\frac{R}{2}\sqrt{\frac{C}{L}}$ (10 marks)

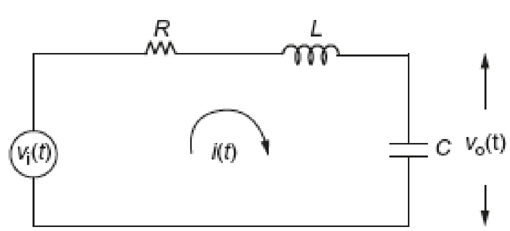


Figure Q 2(c)

(d) A simple gear system is shown in Figure Q2 (d). For the given gear system obtain:

i) The ratio of diameters D_2/D_1 of the gears,
ii) The displacement of gear 2 if gear 1 is displaced by 80 rad,
iii) The angular velocity of gear 2 given the angular velocity of gear 1 as 60 rad/sec,
iv) The angular acceleration of gear 1 given the angular acceleration of gear2 as 8 rad/sec^2 and
v) The torque of gear 2 if the torque of gear 1 is 10 N-m,

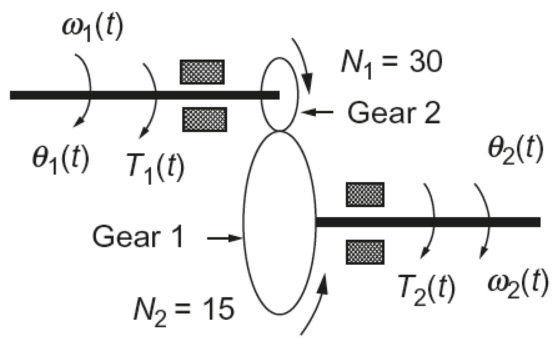


Figure Q 2(d) (5 marks)

Question THREE

(a) Find the response, $c(t)$ to an input, $r(t)=u(t)$, where $u(t)$ is a unit step, assuming zero initial conditions if the transfer function of the system, $G(s)$), is

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

(6 marks)

(b) Define the following terms
i) Rise time
ii) Settling time

(2 marks)

(c) A second order system is described by a differential equation

$$\frac{d^2y}{dt^2}+5\frac{dy}{dt}+9y=9u$$

Determine:
i) the undamped natural frequency, ω_n
ii) the damping ratio, ζ
iii) the time constant τ,
iv) the damped natural frequency, ω_d,
v) characteristic equation for the second-order system

(5 marks)

(d) The system illustrated in figure Q3 (d) is a unity feedback control system with a minor feedback loop (output derivative feedback).
i) In the absence of derivative feedback $(a=0)$, determine the damping factor and natural frequency. Also determine the steady state error resulting from a unit-ramp input.
ii) Determine the derivative feedback constant a of which will increase the damping factor of the system to 0.7. Find also the steady state error to a unit-ramp input with this setting of the derivative feedback constant

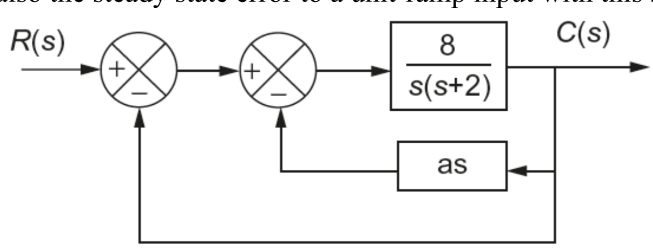


Figure Q 3(d) (7 marks)

Question FOUR

(a) Briefly explain the concept of stability of a control system (2 marks)
(b) The characteristic equation for a feedback control system is given by:

$$s^4+20s^3+15s^2+s+K=0$$

i) Find the range of K for stability
ii) Determine the frequency in rad/sec at which the system will oscillate
iii) Find the number of roots of the characteristic equation that lie in the right half of the s-plane when $K = 5$

(8 marks)

(c) Plot the open loop response on the Nichols chart for a system with unity feedback and an open loop transfer function

$$G(s)=\frac{5}{(s+0.5)(s+1)(s+1.5)}$$

Determine the following:

i) The Phase margin
ii) The Gain margin
iii) Peak magnification and the frequency at which it occurs
iv) The bandwidth

(10 marks)

Question FIVE

(a) State any three advantages of using Bode plot in plotting the frequency response of a system. (3 marks)

(b) State what is meant by a compensating network in a system. (2 marks)

(c) Explain what is meant by a phase lag compensation network and its necessity (2 marks)

(d) Define constant M- and constant N-circles. (2 marks)

(e) Explain how the closed-loop frequency response of the system can be obtained from the open-loop frequency response using constant M - and constant N – circles. (4 marks)

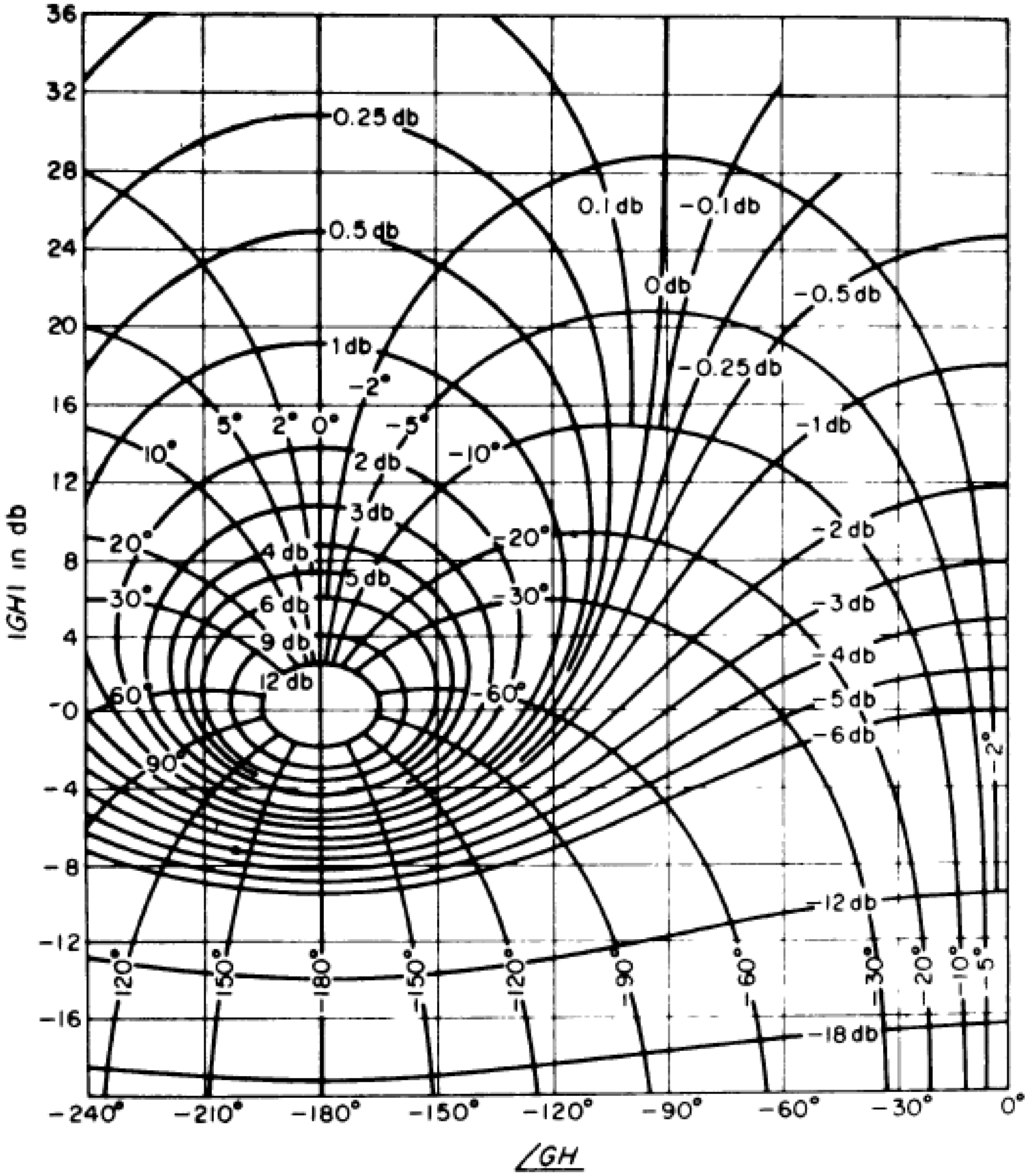
(f) Explain how the steady-state value of the system changes when a PI controller is added to it. (3 marks)

(g) The input and output of a PID controller is related by the equation

$$Q(t)=2Xe+0.5\int Xe\,dt+4\frac{dXe}{dt}$$

Find the value of the proportional gain, the integral time constant and the differential time constant.

(4 marks)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