PP2

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: MARCH 2025 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 TWO Questions.

Do not write on the question paper.

Question ONE

(a) State any two differences between the open loop and the closed loop control systems (2 marks)

(b) With the block diagram, illustrate the control of a car by the driver and identify the components of this closed-loop system (5 marks)

(c) Discuss the concept of negative feedback closed-loop system and derive its transfer function. (5 marks)

(d) A simple open-loop speed control system consists of an electronic amplifier and a motor. The block diagram is shown in Figure Q1 (c) where Vi is the input demand signal. The transfer function, A, for the amplifier is 10 V/V, and that for the motor, M, is 12 (rad/s)/V. Determine the system transfer function, and hence calculate the demand signal required to produce an output speed of 120 rad/s. (3 marks)

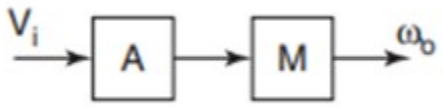


Figure Q 1(c)

(e) The control system in Q1 (c) is converted to a closed-loop system, by the inclusion of a tachogenerator. The transfer function for the tachogenerator, T, is 0.1 V/(rad/s). Sketch the system block diagram, and hence determine the system transfer function, and the input voltage now required to produce an output speed of 120 rad/s. (5 marks)

(f) Obtain the signal flow graph for the block diagram of figure Q1 (f) and hence derive the closed-loop transfer function by using Mason's rule. (10 marks)

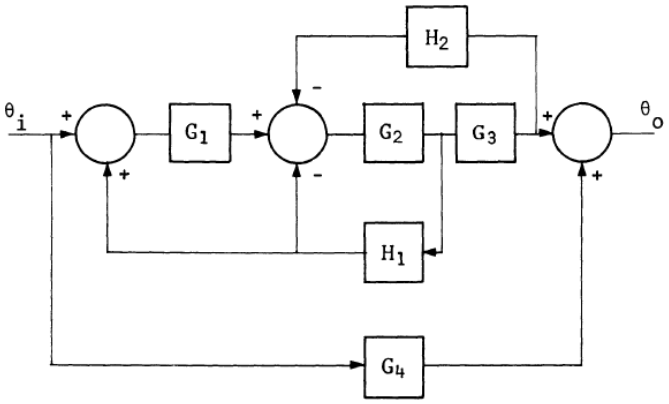


Figure Q1 (f)

Question TWO

(a) Explain the relationship between current and voltage across different ideal elements present in the electrical systems. (3 marks)

(b) State the basic laws used for modeling mechanical systems (2 marks)

(c) State what is meant by free body diagram of a mechanical system (2 marks)

(d) Consider the mechanical system shown in Figure Q 2 (d). Assume that the system is linear. The external force $u(t)$ is the input to the system, and the displacement $y(t)$ of the mass is the output. The displacement $y(t)$ is measured from the equilibrium position in the absence of the external force. Derive the transfer function relating the displacement $y(t)$ to the input force $u(t)$ (3 marks)

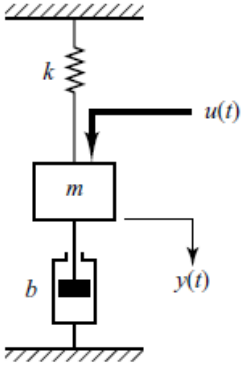


Figure Q 2(d)

(e) For an RLC circuit series network of Figure Q 2(e), 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)

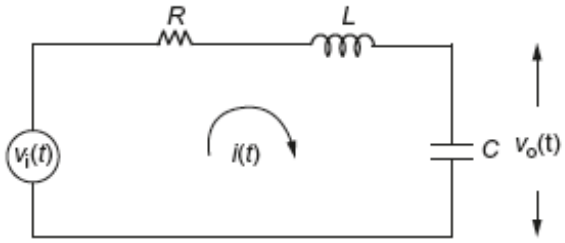


Figure Q 2(e)

Question THREE

(a) State what is meant by time response of a system and what are its components (2 marks)

(b) Define the following standard tests signals used for time-domain studies:

i) impulse signal and unit-impulse signal
ii) step signal and unit-step signal
iii) ramp signal and unit-ramp signal and
iv) parabolic signal

(4 marks)

(c) Derive the response of a first-order system subjected to a unit-step input function (5 marks)

(d) The open-loop transfer function of a closed-loop system with unity feedback is given as:

$$G(s)=\frac{10}{s(0.1s+1)}$$

Evaluate the static error constants and estimate the steady-state errors for step, ramp and acceleration inputs (9 marks)

Question FOUR.

(a) State any two advantages and two disadvantages of frequency response analysis (4 marks)

(b) Construct a Routh table for the following polynomial and state the number of poles in each half plane and hence comment on the overall stability of the system (6 marks)

$$P(s)=3s^7+9s^6+6s^5+4s^4+7s^3+8s^2+2s+6$$

(c) Determine the phase crossover frequency, gain crossover frequency, gain margin and phase margin for the given system with $H(s)=1$ and $G(s)=\frac{1}{s(s+1)(s+0.5)}$ without plotting the Bode plot. Also comment on the stability of the system. (10 marks)

Question FIVE.

(a) Distinguish between absolute stability and relative stability (2 marks)

(b) Define dominant poles and zeros (2 marks)

(c) Determine graphically on a polar curve, the gain margin and phase margin and gain and phase crossover frequencies for the system whose open-loop transfer function is given as

$$G(s)=\frac{8}{(s+1)(s+4)}$$

(10 marks)

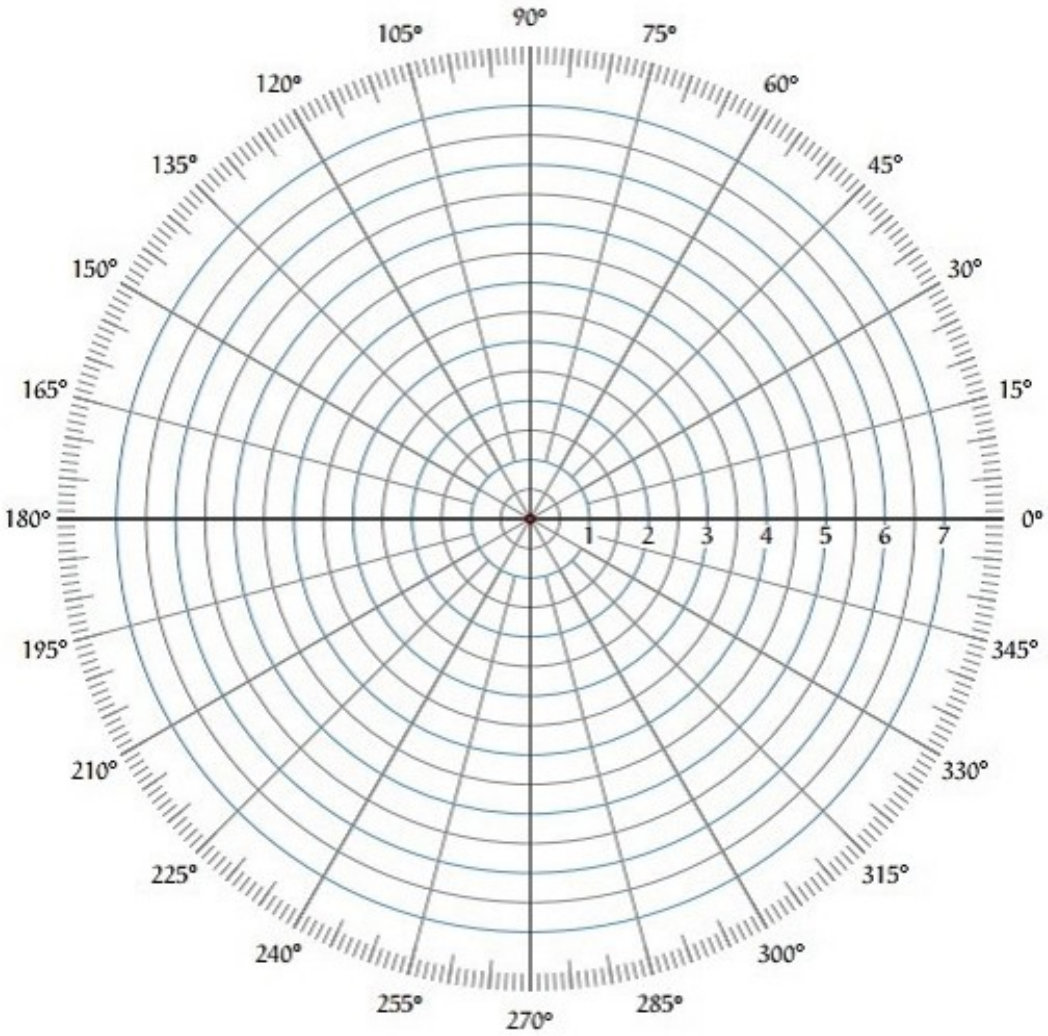
(d) State what is meant by a compensating network in a system. (2 marks)

(e) 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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