



**SCHOOL OF COMPUTING AND ENGINEERING SCIENCES
BACHELOR OF ELECTRICAL AND ELECTRONICS ENGINEERING
END OF SEMESTER EXAMINATION**

BEE 3206: CONTROL SYSTEMS I

DATE: Monday 9th March 2026.

Time: 13.30 - 16.00Hours

Instructions

1. This examination consists of **FIVE** questions.
2. Answer **Question ONE (COMPULSORY)** and any other **TWO** questions.
3. Do not write on the question paper.

QUESTION ONE

(Total:30 Marks)

- a) Using block diagrams, illustrate the difference between Open-loop and Closed-loop system and indicate their general transfer functions (TF). *Provide both +ve and -ve TF for the closed loop system.* (5 Marks)
- b) An autonomous vehicle employs a closed-loop cruise control system to maintain a constant speed despite disturbances such as road gradient and wind resistance. The closed-loop transfer function of the speed control system is given by:

$$G(s) = \frac{50}{s^2 + 8s + 50}$$

- i. Determine; (*Show all the steps*)
 - 1) The Damping ratio (ζ) (2 Marks)
 - 2) The Settling time, assuming a 5% tolerance band (2 Marks)
 - 3) The Peak time (2 Marks)
 - 4) The Maximum Percentage Overshoot (2 Marks)
 - 5) If the system is underdamped, overdamped, critically damped. (1 Mark)
 - 6) The time-domain response of the system to a unit step input using inverse Laplace transform. (3 Marks)
- ii. Using your answers in Qb1(2&4), explain how the vehicle speed response is affected when the cruise control system is engaged. (4) above. (1 Mark)
- iii. Suggest one controller adjustment that would increase damping without significantly increasing the rise time. (1 Mark)
- iv. Discuss the importance of feedback loop in improving speed accuracy and disturbance rejection in autonomous vehicle cruise control systems. (1 Mark)
- v. Determine the closed-loop transfer function TF(s) if the analyzed EV has;
 - 1) Unity feedback, $H(s) = 1$ (2 Marks)
 - 2) Non-unity feedback, $H(s) = \frac{1}{s+2}$ (2 Marks)

- vi. Compare the practical implications of using unity versus non-unity feedback in real cruise control implementations. (1 Mark)
- c) An engineering team is designing the control system for an Autonomous Spaceport Drone Ship (ASDS) used to land reusable rocket boosters at sea. The ship's stability is critical to a successful landing and is managed by an automated feedback system that adjusts the ship's balance using internal mechanisms. The stability of this feedback control system is described by the following characteristic equation, where k is a variable gain parameter that the engineers can tune:

$$s^3 + 2ks^2 + (k + 2)s + 4 = 0$$

Using the Routh-Hurwitz stability criterion, determine the range of values of k for which the system is stable. (5 Marks)

QUESTION TWO

(Total: 15 Marks)

- a) An active suspension system in an electric vehicle regulates vertical body motion to improve ride comfort. Road disturbances are represented by the input $u(t)$, while the vehicle body displacement is the output $y(t)$. The system dynamics are described by the following linear differential equation. Assuming zero initial conditions, determine its transfer function. (7 Marks)

$$6u''(t) - 3u(t) + \int y(t)dt = -3y'''(t) - y(t)$$

- b) For the system shown in figure 1 below,
- Write the systems equation (3 Marks)
 - Draw the Force-current analogy analogous circuit (5 Marks)

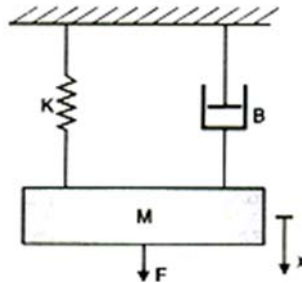


Figure 1

QUESTION THREE

(Total: 15 Marks)

- a) Simplify the block diagram shown in Figure 2 and obtain the closed-loop transfer function $C(s)/R(s)$. (6 Marks)

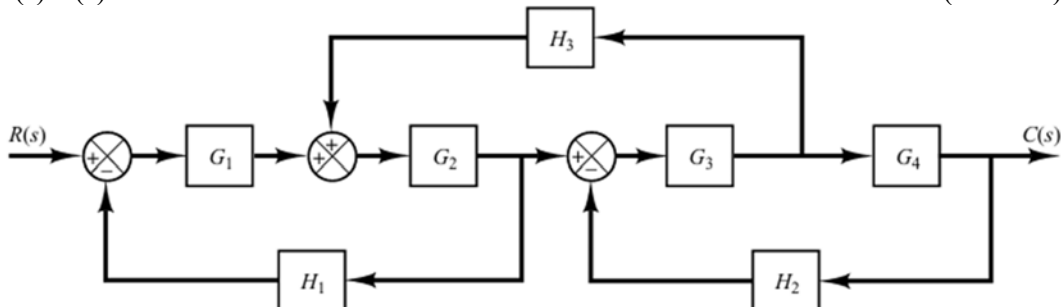


Figure 2

- b) The dynamics of a control system are represented by the signal flow graph shown in Figure 3. Using Mason's Gain Formula, determine the transfer function of the system. (9 Marks)

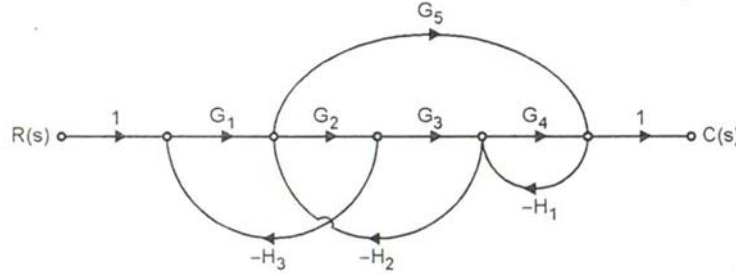


Figure 3

QUESTION FOUR

(Total: 15 Marks)

- a) In high-precision satellite tracking systems, the control loop must handle accelerating targets. The system performance is evaluated by its steady-state error, which represents the difference between the intended position and the actual position as time approaches infinity. Given the plant $G(s) = \frac{1}{s^2(s+12)}$ and the sensor feedback $H(s) = \frac{5(s+1)}{s+5}$, determine the error e_{ss} of this system for step, ramp, and parabolic signals input commands. (10 Marks)
- d) The closed-loop transfer function of the robotic joint mechanism with unity feedback is given by:

$$G(s) = \frac{200}{s(s+8)}$$

Determine the key frequency domain specifications (response magnitude peak, resonant frequency, and bandwidth) of this system. (5 Marks)

QUESTION FIVE

(Total: 15 Marks)

- a) Consider the unity-feedback control system with open-loop transfer function:

$$G(s)H(s) = \frac{k}{s(s+3)(s+6)}$$

Develop the root locus of the system to analyze its stability by completing the following steps:

- Determine the centroid of the asymptotes (2 Marks)
- Calculate the angles of the asymptotes. (3 Marks)
- Find the range of gain k for which the system is stable. (4 Marks)
- Determine the breakaway points on the real axis. (2 Marks)
- Sketch the root locus showing all poles, zeros, asymptotes, and breakaway points. (4 Marks)

Appendices: Laplace Transform Table

	$f(t)$	$F(S)$		$f(t)$	$F(S)$
1.	$\delta(t)$	1		$1 - e^{-at}$	$\frac{a}{s(s+a)}$
2.	$u(t)$	$\frac{1}{s}$		$\frac{1}{a}(at - 1 + e^{-at})$	$\frac{a}{s^2(s+a)}$
3.	$tu(t)$	$\frac{1}{s^2}$		$e^{-at} - e^{-bt}$	$\frac{b-a}{(s+a)(s+b)}$
4.	$t^n u(t)$	$\frac{n!}{s^{n+1}}$		$(1-at)e^{-at}$	$\frac{s}{(s+a)^2}$
5.	$e^{-at}u(t)$	$\frac{1}{s+a}$		$e^{-at} \cos bt$	$\frac{s+a}{(s+a)^2 + b^2}$
6.	$\sin \omega t u(t)$	$\frac{\omega}{s^2 + \omega^2}$		$e^{-at} \sin bt$	$\frac{b}{(s+a)^2 + b^2}$
7.	$\cos \omega t u(t)$	$\frac{s}{s^2 + \omega^2}$		$1 - e^{-at} \left(\cos bt + \frac{a}{b} \sin bt \right)$	$\frac{a^2 + b^2}{s[(s+a)^2 + b^2]}$