

The Open University of Sri Lanka
Faculty of Engineering Technology
Department of Mechanical Engineering



Study Programme : Bachelor of Science Honours in Engineering
Name of the Examination : Final Examination
Course Code and Title : **DMX5403 Control Systems Engineering**
Academic Year : 2024/25
Date : 03rd February 2026
Time : 13:30 – 16:30 hrs.
Duration : **3 hours**

General Instructions

1. Read all instructions carefully before answering the questions.
 2. This question paper consists of **five (5)** questions on **four (4)** pages.
 3. Write the answers for **Section A** and **Section B** in separate answer books.
 4. Answer all questions.
 6. This is a **Closed Book Test (CBT)**.
 7. Answers should be in clear handwriting and do not use Red colour pen.
 8. Clearly state your assumptions, if any.
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SECTION A

- Q1** Figure 1 shows the cross section of a magnetic levitation train providing a high-speed, very low friction alternative to steel wheels on steel rails. The track is a T-shaped guideway and the train floats on an air gap d as shown in the figure. Electromagnets are distributed along the guideway in matched pairs.

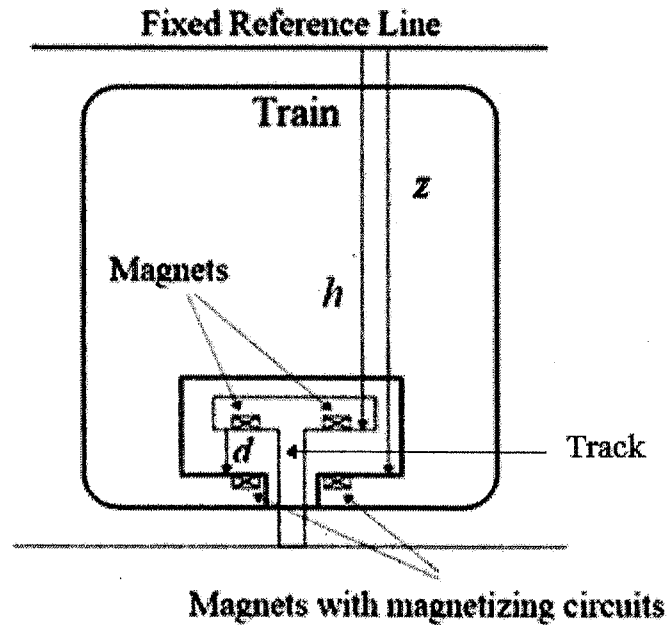


Figure 1

- State three advantages of a magnetic levitation train system as opposed to a traditional train system. [06]
- By studying Figure 1, briefly explain how to control the air gap d within a close tolerance in normal operation of this control system. [06]
- State the relevant components from Figure 1 for the following blocks: [06]
plant, sensor, actuator, controller, reference.
- Draw the block diagram with the relevant components for the system. [02]

Q2

- Figure 2(a) shows a unity gain buffer amplifier system. Using basic principles, establish transfer function $\frac{V_o(s)}{V_i(s)}$. [09]

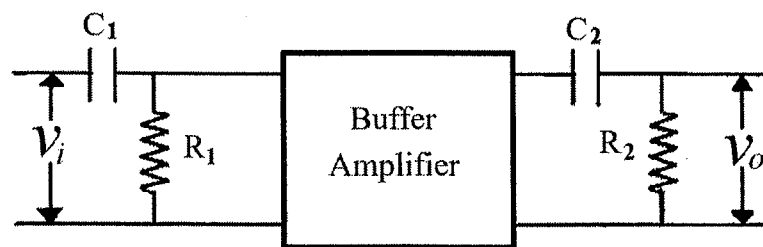


Figure 2(a)

- b) Find $\frac{C(s)}{R(s)}$ when $N(s) = 0$, for the system shown in Figure 2(b).

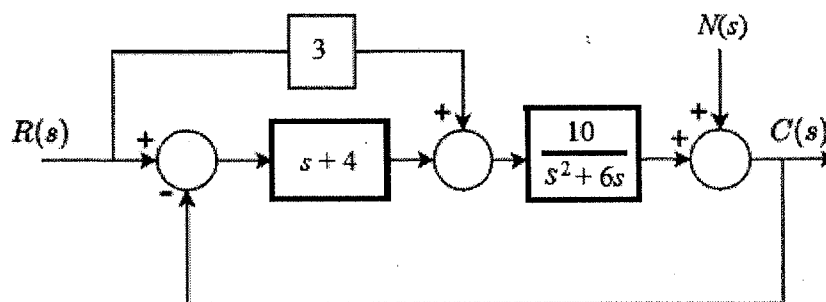


Figure 2(b)

SECTION B

Q3

- a) Under what conditions would the Routh-Hurwitz criterion easily tell us the actual location of the system's closed-loop poles? [05]
- b) Given the unity feedback system of the figure 3(a) with,

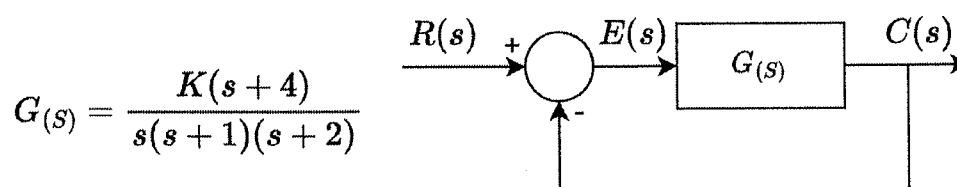


Figure 3(a)

- i) The range of K that keeps the system stable. [04]
- ii) The value of K that makes the system oscillate. [03]
- iii) The frequency of oscillation when K is set to the value that makes the system oscillate. [03]
- c) Draw the Nyquist contour in S-Plane whose open loop transfer function is, [05]

$$G(s)H(s) = \frac{K}{s(s+2)(s+10)}$$

Q4

- a) The open loop transfer function of a unity negative feedback system is given by,

$$G(s) = \frac{K(s+9)}{s(s^2 + 4s + 11)}$$

Sketch the Root Locus of the system and hence find the range of K to keep the system stable.

[08]

b) Define **gain margin** and **phase margin** in the context of frequency response analysis for feedback control systems. [04]

c) Plot the Bode diagram for the following transfer function. [08]

$$G(s) = \frac{10}{s(1 + 0.4s)(1 + 0.1s)}$$

Q5

Consider a temperature controller with a control system as shown in Figure 5 and the plant transfer function

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

and $G_c(s)$ is selected as a PID controller so that the steady state error for a unit step input is equal to zero.

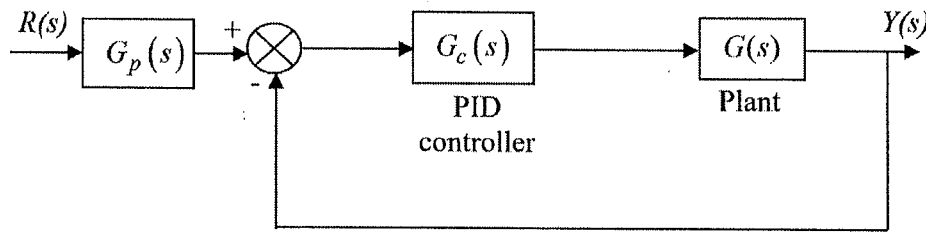


Figure 5: PID controlled temperature control system

a) Obtain the closed-loop transfer function without a prefilter (i.e., $G_p(s) = 1$). [04]

b) Determine a suitable $G_c(s)$ so that

i) The characteristics equation of the closed-loop transfer function with optimum coefficients be $s^3 + 1.75\omega_n s^2 + 2.15\omega_n^2 s + \omega_n^3$. [04]

ii) The percentage overshoot for a step input is 2% or less. [04]

[Hint: Percentage overshoot = $100\exp^{-\zeta\pi/\sqrt{1-\zeta^2}}$]

iii) Settling time (2% criterion) is less than 0.5 second. [04]

[Hint: Settling time (2% criterion) = $\frac{4}{\zeta\omega_n}$]

where ζ and ω_n are damping ratio and natural frequency respectively.

c) Determine the prefilter transfer function to eliminate the zeros in the closed loop transfer function obtained in part (a) above together with PID parameters obtained in part (b) above and bring the overall numerator of the closed-loop transfer function to 1000. [04]

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