

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/ DMX4543 Control Systems Engineering
Academic Year	: 2022/23
Date	: 16 th February 2024
Time	: 09:30 – 12:30 hrs.
Duration	: 3 hours

General Instructions

1. Read all instructions carefully before answering the questions.
 2. This question paper consists of **five (5)** questions in **Six (6)** pages.
 3. Write the answers for the **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

- (a) Figure 1(a) shows a closed loop control system which is used to maintain the liquid level of a tank. Here, our objective is to keep the liquid level at the height of h_1 . The existing liquid level is h_2 and T1, T2 are the inlet valve and outlet valve respectively.

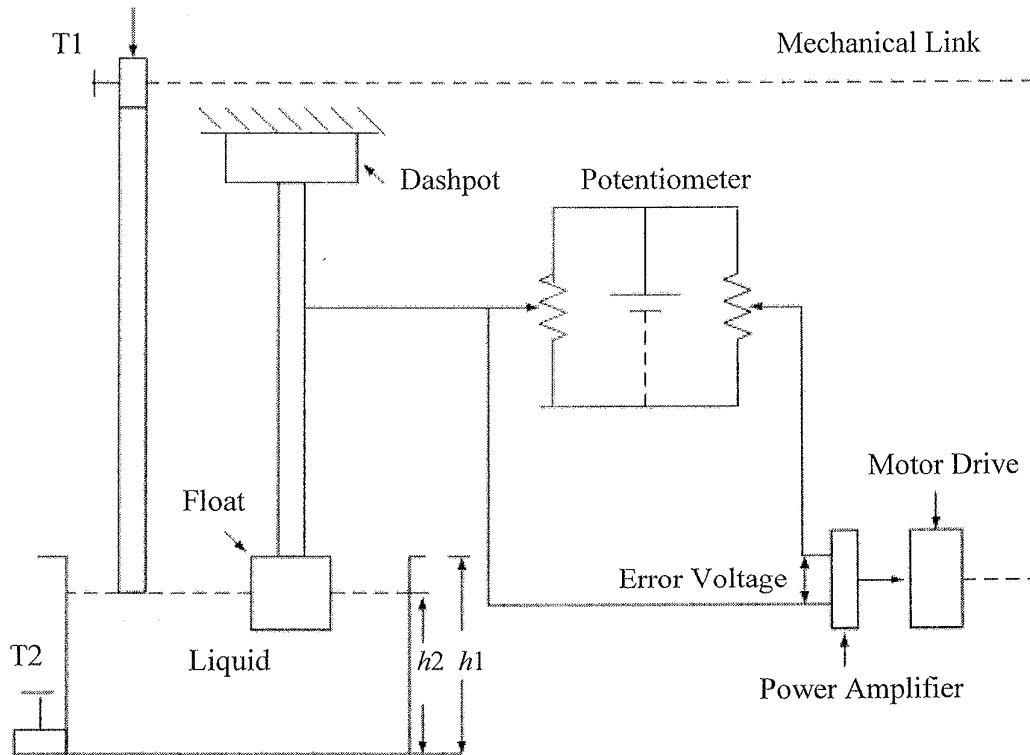


Figure 1(a)

- By studying the given schematic diagram, explain the operation of this liquid level control system. **[04 marks]**
- Draw a complete block diagram and write down the functions of each unit. **[04 marks]**
- Briefly explain the following for the given system. **[04 marks]**
 - Linear and Nonlinear
 - Comparison of response time

- (b) Figure 1(b) shows a system for controlling the temperature of a liquid in a chemical processing plant (with $G(s)$). The liquid is heated by steam and a temperature transducer (gain K_T) measures the temperature. A controller (gain K_C) detects the error between the set point and measured temperature of the liquid and accordingly operates a control value (assume that it is linear with gain K_V) in the steam supply line.

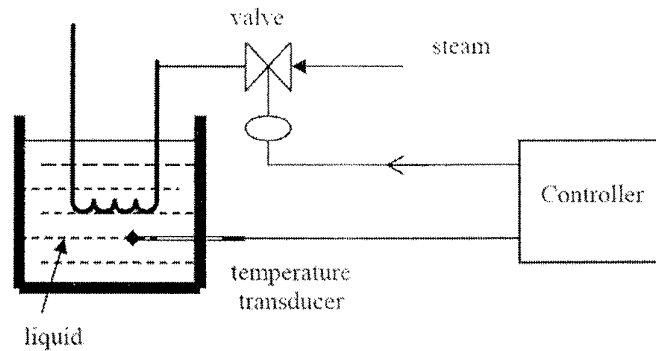


Figure 1(b)

Draw the complete block diagram of the system and obtain the following. [08 marks]

- | | |
|-------------------------------------|----------------------------------|
| (i) Forward transfer function | (ii) Open loop transfer function |
| (iii) Closed loop transfer function | (iv) Error function |

Q2

A control-system engineer is designing a feedback amplifier using two stages of gain. He is not certain which of the following two systems (see Figure 2) will result in a smaller sensitivity to the amplifier gain, K_a

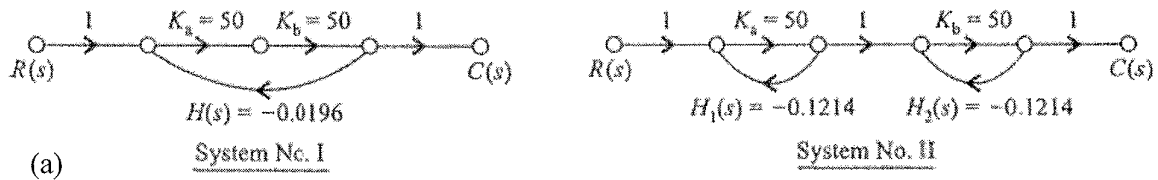


Figure 2

- (a) Explain briefly, what is meant by *sensitivity* of a system. [03 marks]
- (b) Determine the closed-loop transfer functions, $C(s)/R(s)$, for each design, assuming that $K_a = K_b = 50$. [04 marks]
- (c) Compare the sensitivities of the two systems with respect to the amplifier gain K_a . [08 marks]
- (d) Why do the results come out of the way they do, and which design would you select? [05 marks]

SECTION B

Q3

a) Explain the following terms briefly:

- i) Absolute stability and relative stability.
- ii) Stability analysis in s-plane.
- iii) Complementary Root Loci (CRL)
- iv) Root Contours (RC)

[04 marks]

b) Find the maximum value of 'K' for which the system is stable.

$$G(s)H(s) = \frac{Ke^{-2s}}{s}$$

[05 marks]

c) The open loop transfer function of a unity feedback control system is given by,

$$G(s) = \frac{K}{s(s+2)(s+3)}$$

Where K is the gain of the controller.

- i) Draw the root locus diagram as a function of K and determine the range of K for which the system is stable.
- ii) Determine the gain of the controller which gives a damping ratio of 0.5 of the system.
- iii) Using the root locus you have drawn show that $s = -4$ is a closed loop pole of a system when $K = 8$.

[11 marks]

Q4

a) The asymptotic Bode magnitude plot of a system is sketched in Figure Q4. Write the expression for its transfer function in the frequency domain.

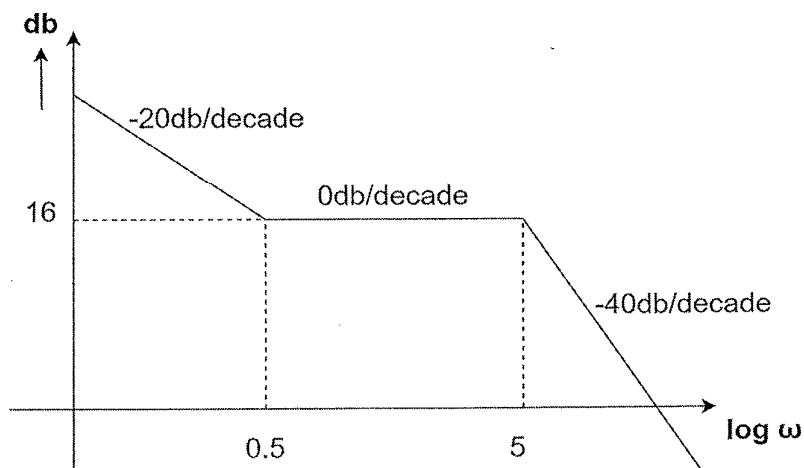


Figure Q4 a)

[05 marks]

b) Explain the differences between the controller and compensators.

[04 marks]

c) The plant to be controlled is described by the transfer function.

$$G_P = \frac{280(s + 0.5)}{s(s + 0.2)(s + 5)(s + 70)}$$

The bode plot for $G_P(s)$ and $K_c G_P(s)$, K_c are shown in Figure Q4 c)

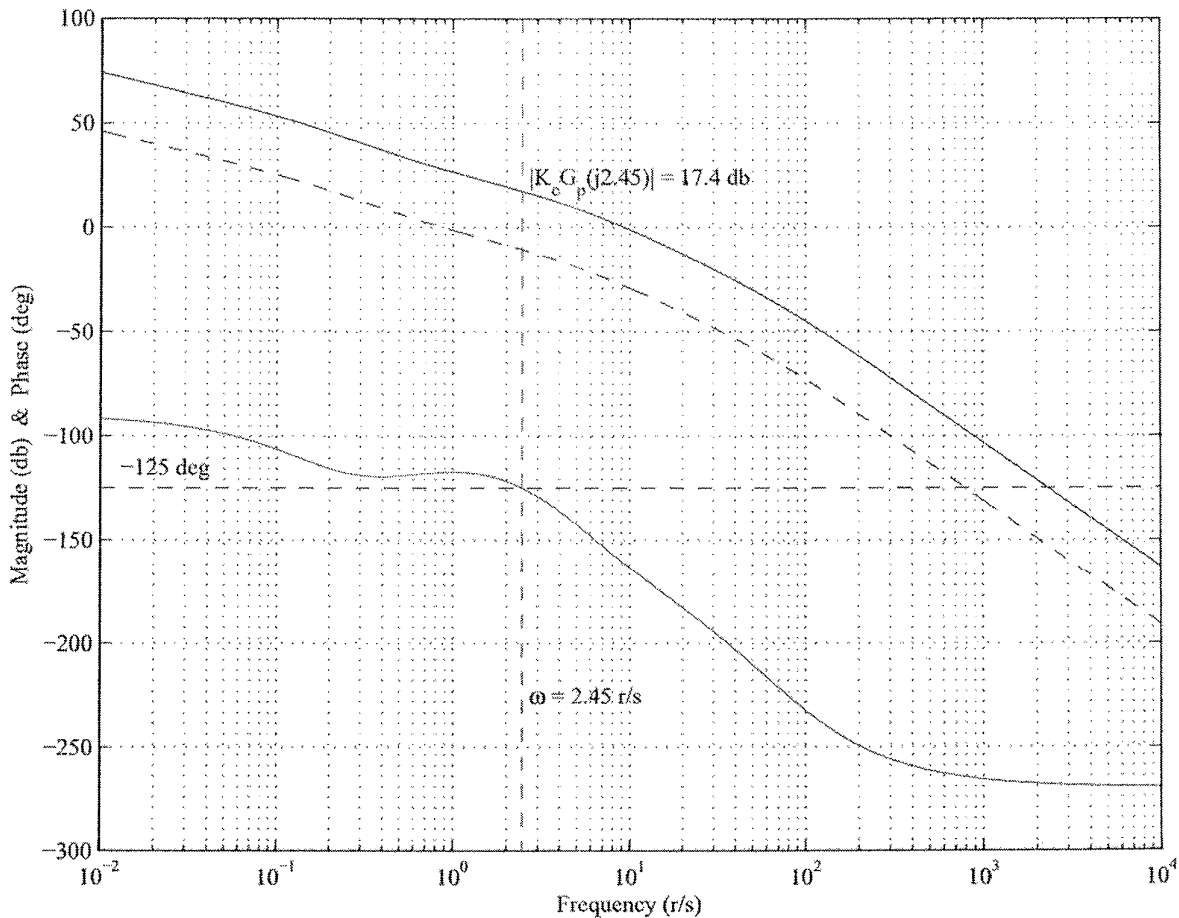


Figure Q4 b)

It is desired to have the following specifications.

- Steady-state error for a ramp input ≤ 0.02 .
- Phase margin $\geq 45^\circ$

Design a suitable compensator.

$$\left(\text{Hint: } K_V = \lim_{s \rightarrow 0} sG(s), \text{ } ESS_{\text{plant}} = \frac{1}{K_V}, K_c = \frac{ESS_{\text{plant}}}{0.02} \right)$$

[11 marks]

Q5

- a) Explain how varying PID controller parameters impact system performance.

[05 marks]

- b) A PID controller is given by $u(t)_{PID} = 10e(t) + 6.5\dot{e}(t) + 15 \int e(t) dt$. Identify controller gains, then, incorporate this PID controller into a unit negative feedback control system by representing it as a block diagram. Additionally, provide the plant transfer function for integration into the block diagram representation.

$$G_P = \frac{280(s + 0.5)}{s(s + 0.2)(s + 5)(s + 70)}$$

[05 marks]

- c) Consider the cascade sample data system shown in figure Q5.

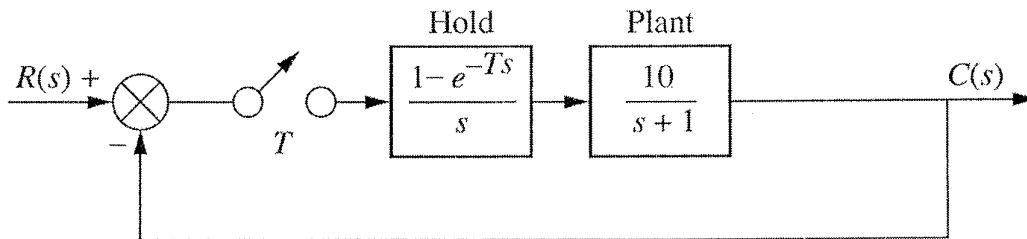


Figure Q5

- i) Find the z domain transfer function of the system.

[05 marks]

- ii) Determine the range of sampling interval, T, that will make the system stable.

[05 marks]

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