

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 : 2023/24
Date : 11th February 2025
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 in **Four (4)** 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 sample of James Watt's steam engine developed in 1769 which is the first automatic feedback controller used in an industrial process. Here, our objective is to control the speed of the steam engine.

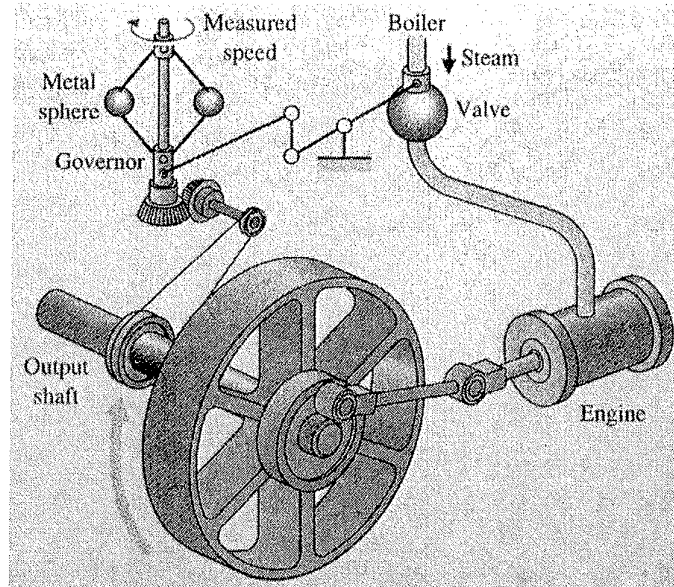


Figure 1(a)

- I By studying the given figure, briefly explain the operation of this control system. [05]
- II State the relevant components from the figure for the following blocks: [05]
plant, sensor, actuator, controller, reference.

- (b) Obtain the transfer function (in S-domain) for the given electro-mechanical system shown in Figure 1(b). The term k_b is the back electromotive force constant in $\text{Vm}^{-1}\text{s}^{-1}$ and all other terms are in standard notation. [10]

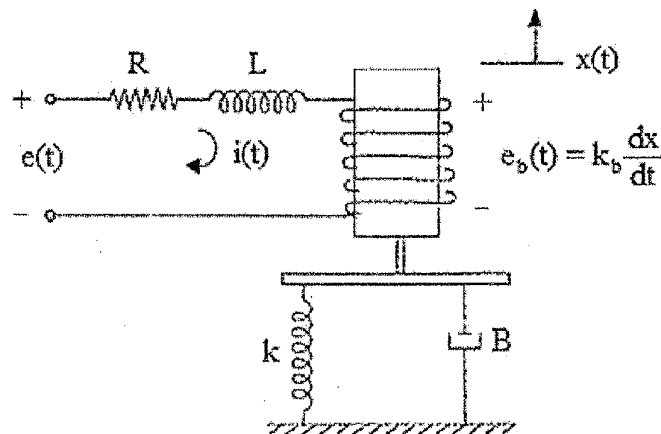


Figure 1(b)

Q2

Figure 2(b) is the simplified version of Figure 2(a). Answer the following questions.

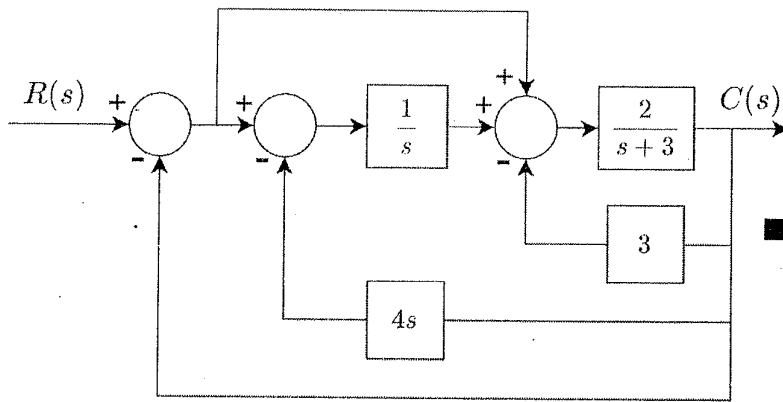


Figure 2(a)

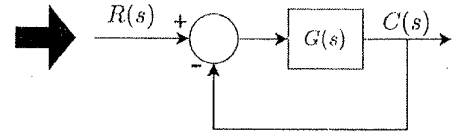


Figure 2(b)

(a) By showing the steps, simplify the system shown in Figure 2(a) into Figure 2(b) and obtain the transfer function for $G(s)$. [11]

(b) Compute the steady-state error for the system $G(s)$, when the following input is applied:

I $5u(t)$

II $5tu(t)$

III $5t^2u(t)$

where $u(t)$ is the unit step function.

[09]

SECTION B

Q3

a)

I. "The Routh-Hurwitz criteria give absolute stability of the system" Justify your answer. [06]

II. A servo drive based unity feedback control system is shown in Figure 3(a).

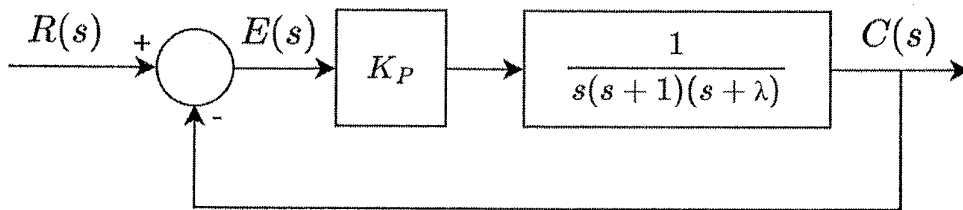


Figure 3(a)

Determine the parameter λ ensuring system stability for $0 \leq K_p \leq 2$ using Routh-Hurwitz stability criterion. [08]

b) Explain the **Nyquist stability criterion** and discuss the step-by-step procedure for analyzing system stability using this method. [06]

Q4

- a) A closed loop control system has an open loop transfer function

$$G(s)H(s) = \frac{K(s+2)}{(s^2+2s+4)} = \frac{K(s+2)}{(s+1+j\sqrt{3})(s+1-j\sqrt{3})}$$

Find the root locus as K varies from 0 to ∞ , hence find the range of K to keep the system stable.

[10]

- b) Plot the Bode magnitude for the system with transfer function.

$$G(s) = \frac{2000(s+0.5)}{s(s+10)(s+50)}$$

[10]

Q5

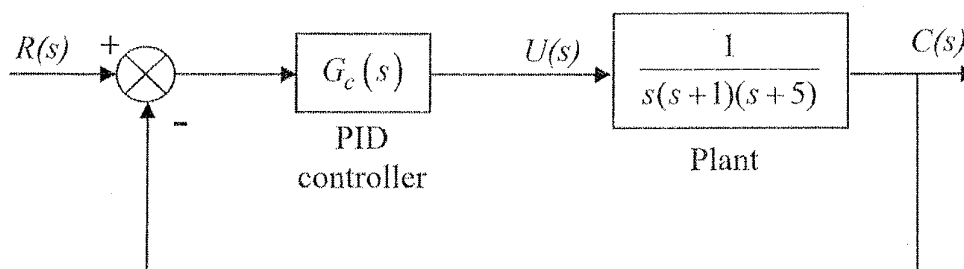


Figure Q5

Consider the control system shown in Figure Q5 in which a PID controller is used to control the system. The PID controller has a transfer function.

$$G_c(s) = K_p \left(1 + \frac{1}{T_i s} + T_d s \right)$$

- Obtain the closed-loop transfer function of the system setting: $T_i = \infty$ and $T_d = 0$. [05]
- Find the value of the critical gain K_{cr} that makes the system marginally stable so that sustained oscillation occurs. (Hint: Use Routh's stability criterion, $K_{cr} = K_p$) [05]
- Find the frequency of the sustained oscillation ω (Hint: $s = j\omega$) and period of sustained oscillation P_{cr} (Hint: $P_{cr} = \frac{2\pi}{\omega}$). [05]
- Using the second method of Ziegler-Nichols tuning rules determine the values of K_p , K_i , and K_d . Refer Table Q5.

Table Q5: Ziegler-Nichols Tuning Rule Based on Critical Gain K_{cr} , and Critical Period P_{cr}

Type of Controller	K_p	T_i	T_d
PID	$0.6K_{cr}$	$0.5P_{cr}$	$0.125P_{cr}$

[05]

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