60

(University of Choice)

MASINDE MULIRO UNIVERSITY OF SCIENCE AND TECHNOLOGY (MMUST)

MAIN CAMPUS

UNIVERSITY EXAMINATIONS
2023/2024 ACADEMIC YEAR

FOURTH YEAR FIRST SEMESTER EXAMINATIONS

FOR THE DEGREE
OF
BACHELOR OF SCIENCE IN MECHANICAL AND INDUSTRIAL ENGINEERING

COURSE CODE: MIE 453

COURSE TITLE: CONTROL ENGINEERING

DATE: WEDNESDAY 06/12/2023 TIME: 12: 00 PM – 2:00 PM

INSTRUCTIONS TO CANDIDATES

ANSWER QUESTION ONE AND ANY OTHER TWO QUESTIONS.
QUESTION ONE CARRIES 30 MARKS AND ALL OTHERS 20 MARKS EACH.

TIME: 2 Hours

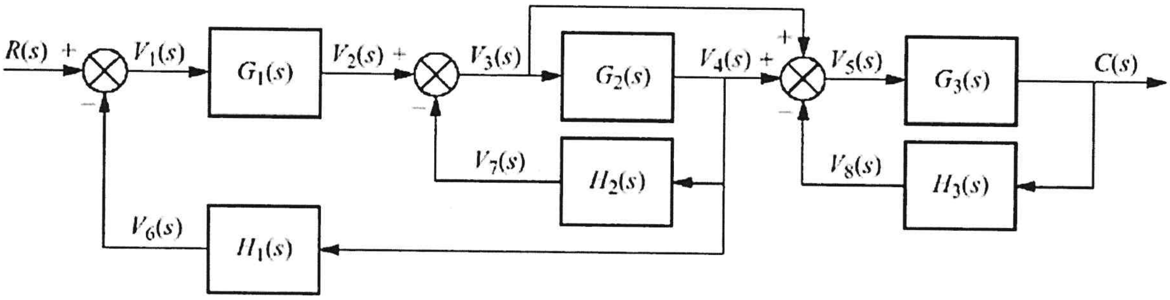
This Paper Consists of 4 Printed Pages. Please Turn Over.

QUESTION ONE (COMPULSORY) (30 MARKS)

1. In a table format differentiate between open loop and closed loop control systems.

[4 Marks]

2. Consider the block diagram below.



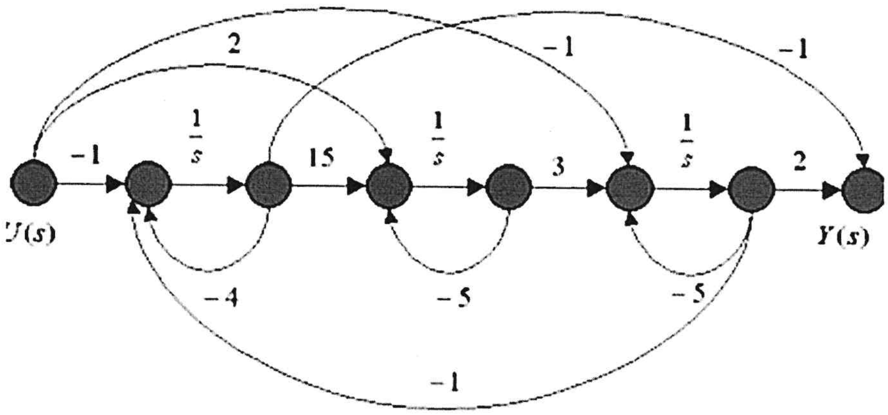
i. Simplify the block diagram using the block diagram reduction rules
ii. Determine the transfer function of the system.
iii. Convert the block diagram into its equivalent signal flow graph

[10 Marks]

3. Differentiate the following terms as applied in system response and illustrate their relationship with reference to frequency response and time response.
   i. Bandwidth and rise time
   ii. Resonant peak and peak overshoot

[4 Marks]

4. Consider a system described by the signal flow graph as shown below. Find its transfer function, $G(s) = \frac{Y(s)}{U(s)}$, using the Mason's Gain formula



[8 Marks]

5. Differentiate between the necessary condition and sufficient condition for stability in Routh-Hurwitz Stability Criterion.

[4 Marks]

QUESTION TWO (20 MARKS)

a) Consider the system shown in Figure 1 below. To improve the performance of the system feedback is added to this system, which results in Figure 2. Determine the value of K so that the damping ratio of the new system is 0.4. Compare the overshoot, rise time, peak time and settling time and the nominal value of the systems shown in Figures 1 and 2.

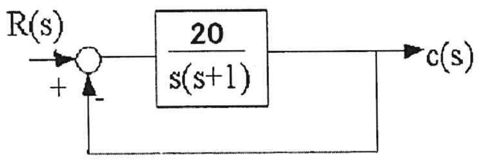


Figure 1

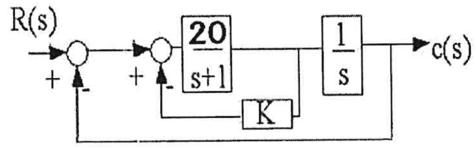


Figure 2

[10 Marks]

b) A single degree of freedom spring-mass-damper system has the following data: Spring stiffness = 20 kN m^{-1}, mass = 0.05 kg, and damping coefficient = 20 Ns m^{-1}. Determine the following

i. The undamped natural frequency in rad s^{-1} and Hz
ii. The damping factor
iii. The damped natural frequency in rad s^{-1} and Hz.

[6 Marks]

c) Which type of standard test signal is widely used the time domain for analyzing the control systems from their responses and discuss the reasons why it's widely used.

[4 Marks]

QUESTION THREE (20 MARKS)

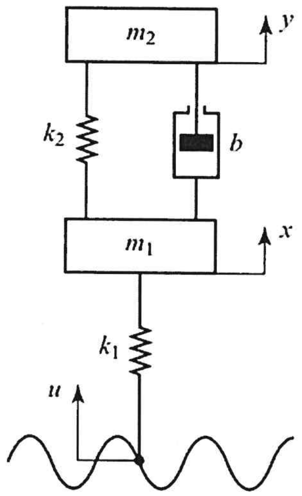
a) Sketch the polar plot for the following open loop transfer function with unity feedback

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

[8 Marks]

b) Consider a mechanical system shown below of a simplified version of an automobile or motorcycle suspension system. Given that m_2 is mass of the car, m_1 is unsprung mass k_2 and b are the suspension, k_1 is tire stiffness, and u is the ground motion displacement input.

i. Obtain the transfer function model of the mechanical system shown in the following Figure if the input u is a displacement input. Assume that displacements x and y are measured from their respective steady-state positions in the absence of the input u
ii. Represent the above mechanical system in a block diagram



[6 Marks]

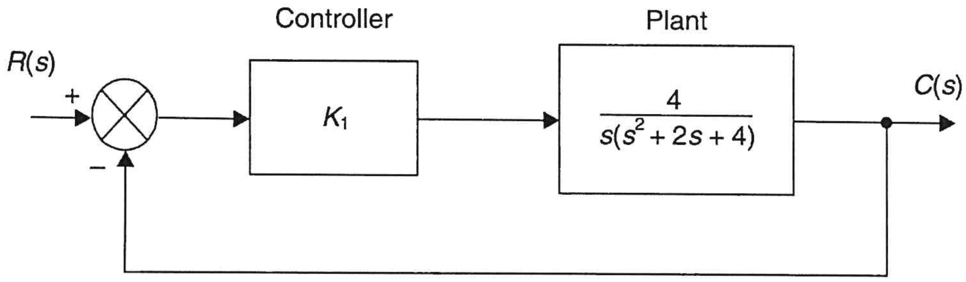
c) Using clear block diagrams highlight on the three compensator configurations

[6 Marks]

QUESTION FOUR (20 MARKS)

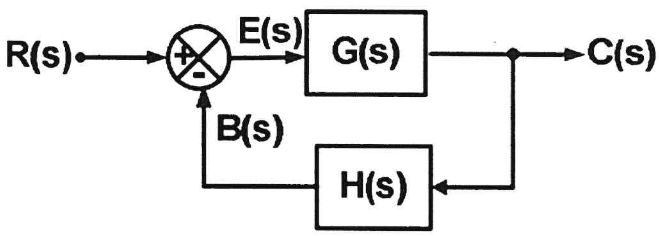
a) Construct the Nyquist diagram for the control system shown below and determine:

i. Gain margin
ii. Phase margin
iii. The controller gain K_1 that makes the system just unstable.



[12 Marks]

b) Consider a closed loop control system below,



If $G(s) = \frac{10(1+s)}{s^2(5s+6)}$, $H(s) = 5$, and $r(t) = \left(1.9 + 4.6t + \frac{3.8t^2}{2}\right)u(t)$. Find the steady state error of the system using generalized error constants when subjected to an input signal given by $r(t)$

[6 Marks]

c) In a table format differentiate on the effects of a lead and lag compensator on a system.

[2 Marks]

QUESTION FIVE (20 MARKS)

a) A control system has the following open-loop transfer function;

$$G(s)H(s) = \frac{k}{s(s+2)(s+5)}$$

i. Obtain the following;

1. Asymptotes
2. Breakaway point
3. Imaginary axis crossover point
4. The value of K for marginal stability
5. Sketch the root locus diagram

ii. Locate a point on the locus that corresponds to a damping ratio of 0.5 and find the value of K for this condition.

[12 Marks]

b) Using Routh-Hurwitz Stability Criterion, determine the stability of the system having characteristic equations below

$$s^5 + 2s^4 + 4s^3 + 8s^2 + 3s + 1 = 0$$

[6 Marks]

c) Highlight on at least two types of systems based on stability.

[2 Marks]