GLASGOW COLLEGE UESTC

Main **Exam**

Dynamics and Control (UESTC 3001)

Date: June 17th, 2024
Time: 09:30-11:30AM

Attempt all PARTS. Total 100 marks

Use one answer sheet for each of the questions in this exam.
Show all work on the answer sheet.

Make sure that your University of Glasgow and UESTC Student Identification Numbers are on all answer sheets.

An electronic calculator may be used provided that it does not allow text storage or display, or graphical display.

All graphs should be clearly labelled and sufficiently large so that all elements are easy to read.

The numbers in square brackets in the right-hand margin indicate the marks allotted to the part of the question against which the mark is shown. These marks are for guidance only.

DATA/FORMULAE SHEET IS PROVIDED AT THE END OF PAPER

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Q1

a) What is the logical sequence involved in the design of a feedback control system? Explain with an appropriate diagram. [7 marks]

b) Figure Q1 shows the block diagram of a control system. Using block diagram reduction techniques, reduce it to a single block. Ensure that you illustrate the intermediate steps of your simplification process. [12 marks]

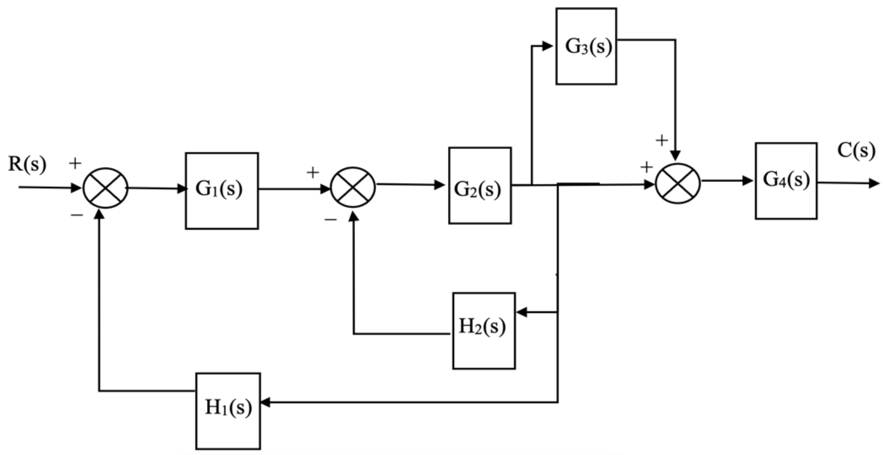

Figure Q1

c) Identify the key components and design a block diagram for an autopilot system which enables a plane to follow a predefined flightpath. Note, that the primary control surfaces (ailerons, elevators, and rudders) enable the aircraft to perform essential manoeuvres, and Global Positioning System (GPS) enhances precision in tracking. [6 marks]

Q2

a) The representation of a first-order system with proportional feedback control is illustrated in Figure Q2.

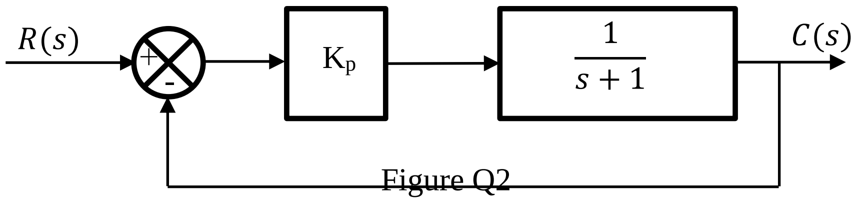

Figure Q2

i) For a unit step input, find the final response of the system. Take K_p as 2. [6 marks]

ii) Obtain the steady-state error of the system in response to a unit step input. [6 marks]

b) Given the transfer function below, find the poles and zeros of the system. [5 marks]

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$$\frac{Y(s)}{R(s)} = \frac{2\varsigma\omega_n s + \omega_n^2}{s^2 + 2\varsigma\omega_n s + \omega_n^2}$$

Assume ω_n = 3 rad/s and ς = 1.

c) Explain why it is common in practical control system applications to enhance derivative control with proportional control. Highlight the reasons for this augmentation, emphasizing the complementary nature of proportional and derivative control mechanisms. Additionally, elaborate on how this combination contributes to improved system stability, responsiveness, and overall performance.

[8 marks]

Q3

Consider the system in Figure Q3:

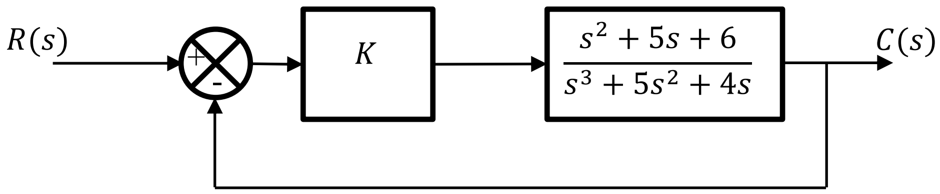

Figure Q3

a) Show how the closed loop characteristic equation can be determined. [5 marks]

b) For the system given in Figure Q3, you have been asked to use the root locus method to analyze the behavior of the closed loop poles as a function of the gain (K). To support your analysis, carry out the following steps:

i. Find the open loop zeros and the open loop poles. [4 marks]

ii. Sketch the real axis segments that are to be included in the root locus. [2 marks]

iii. Determine the number of asymptotes, the centroid where the asymptotes intercept with the real axis, and angles of the asymptotes. [3 marks]

iv. Determine the breakaway points where the locus leaves the real axis. [3 marks]

v. Sketch the root locus using the information you have computed in i to iv above. [3 marks]

c) Using the Route Hurwitz criterion, discuss the stability of the system as the open loop gain K ranges from 0 to ∞. [5 marks]

Q4

You have been invited to analyze the frequency response characteristics of a robotic arm with the control system given in Figure Q4.

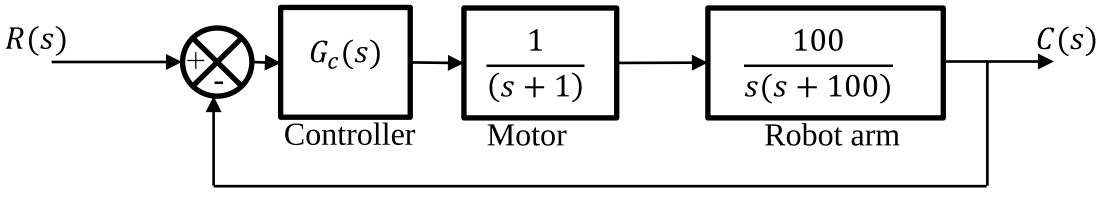

Figure Q4

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a) Taking the controller gain $G_c(s) = K$, determine the factors composing the transfer function in time constant form and identify their corresponding corner frequencies (if necessary, assume $K = 1$). [6 marks]

b) Compute the slopes and phase angles attributed to the primary factors within the transfer function. [6 marks]

c) Draw a Bode plot showing magnitude in decibels and phase angle in degrees over a logarithmic frequency scale. Assume that $K = 1$ [6 marks]

d) Explore the system's behavior under the condition that K = 20 by:

   i. generating a revised Bode plot. [4 marks]

   ii. Write a reflection on how the adjustment in K impacts both the gain crossover frequency and the phase crossover frequency [3 marks]

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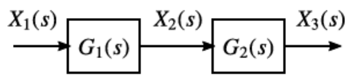
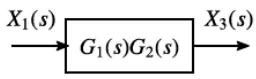
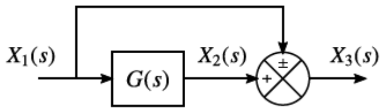
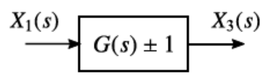
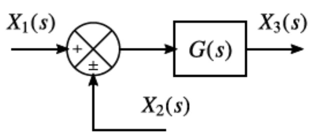
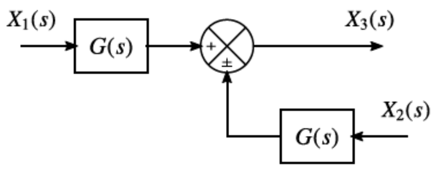
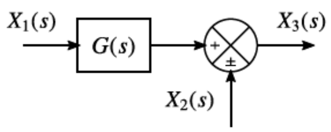
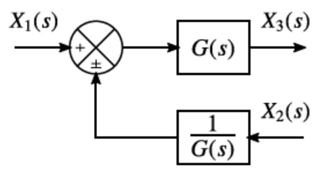
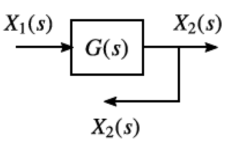
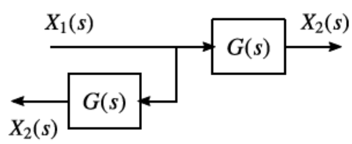
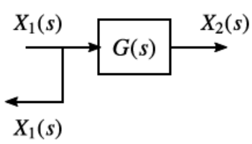
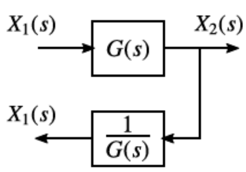
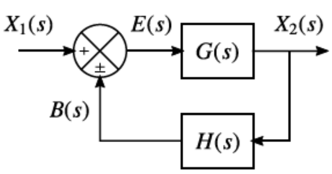
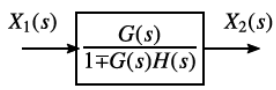
Appendix

Rules for block diagram reduction

Rule	**Original**	**Equivalent**
1. Cascaded blocks		
2. Summing two signals		
3. Moving a summing point behind a block		
4. Moving a summing point ahead of a block		
5. Moving a branch point ahead of a block		
6. Moving a branch point behind a block		
7. Eliminating a feedback loop		

End of question paper