College of Science

School of Engineering

Time Constrained Assessment

Module Title	Control Systems
Module Code	EGR2006M
Module Coordinator	Prof Timothy Gordon
Duration of Assessment	4.5 hours
Date	30 May 2023
Release Time	11:30 - British Summer Time (BST)
Submission Time	16:00 - British Summer Time (BST)

General Instructions to Candidates.

1. You **must** submit your answers to TurnItIn on Blackboard **before** the submission time: failure to do so will be classified as misconduct in examinations. We strongly recommend you submit 15 minutes prior to the deadline.
2. You **must** also send a copy of your work to: soesubmissions@lincoln.ac.uk at the same time. You must place the Module Code and your Student Id in the Subject Field of the Mail.
3. For students who choose to word process their answers, hand-written notes or diagrams, **must** be photographed (preferably using Microsoft Lens which is available as part of your Office 365 package) and inserted into the Word Document as an image.
4. This assessment is an open resource format: you may use online resources, lecture and seminar notes, textbooks and journals.
5. All work will be subject to plagiarism and academic integrity checks. In submitting your assessment, you are claiming that it is your own original work; if standard checks suggest otherwise, Academic Misconduct Regulations will be applied.
6. The duration of the Time Constrained Assessment will vary for those students with Learning Support Plans (LSPs). Extensions do not apply, but Extenuating Circumstances can be applied for in the normal way.

Module Specific Instructions to Candidates

1. Answer All FOUR Questions.
2. All questions carry EQUAL marks.

Question One

The system shown in Figure 1 consists of a controller $C(s)$ and plant $G(s)$ with adjustable gain $K > 0$.

a. Determine the (open-loop) transfer function

$$\frac{Y(s)}{R(s)} = C(s)G(s)$$

(8 marks)

b. State the order and type of $C(s)G(s)$. **(5 marks)**

c. Sketch the block diagram for the closed-loop system which has unity feedback and $C(s)G(s)$ in the forward path. Also determine the steady-state error when the reference signal is (i) a unit step , (ii) a unit ramp. **(10 marks)**

d. Comment on how the value of K affects steady-state error. **(2 marks)**

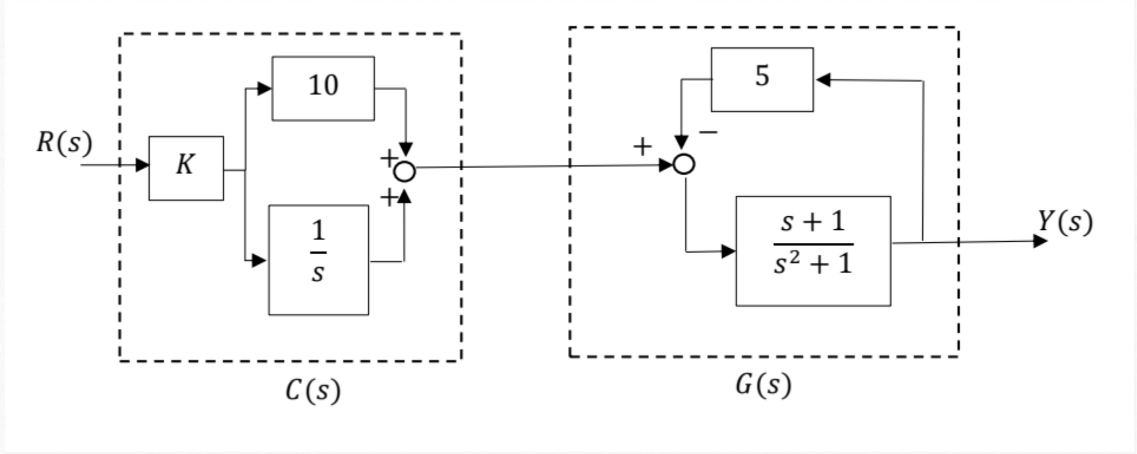

Figure 1

Question Two

For the system shown in Figure 2,

$$G(s) = \frac{(s+4)}{(s+1)(s+2)(s+3)} \quad , \quad H(s) = 1$$

a. Sketch the root locus, explaining all of its key features, including the location of any asymptotes. *Note*: there is no need to determine the precise location of any points where the root locus breaks away from the real axis. **(15 marks)**

b. Find the range of values for the controller gain $K \geq 0$ for which the system will be stable. **(4 marks)**

c. Estimate the 5% settling time of the closed-loop system when K is large. **(6 marks)**

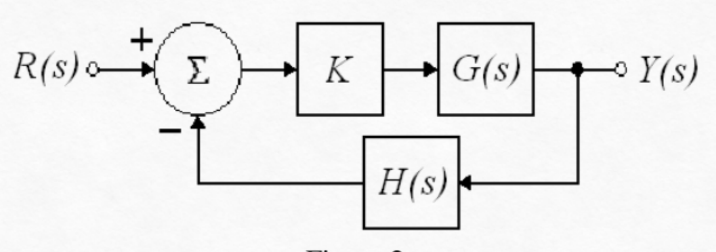

Figure 2

Question Three

For the following plant transfer function:

$$G(s) = \frac{s+10}{s^5 + 10s^4 + 47s^3 + 102s^2 + 90s}$$

a. The Routh-Hurwitz condition implies that $G(s)$ is not stable – explain. **(3 marks)**

b. Evaluate the transfer function

$$T(s) = \frac{KG(s)}{1 + KG(s)}$$

and write down the characteristic polynomial. **(10 marks)**

c. Use the Routh-Hurwitz condition to test whether $T(s)$ is stable for K =10. **(12 marks)**

Question Four

This question concerns the PD (proportional-derivative) feedback control of a plant with transfer function

$$G(s) = \frac{1}{s^2 + 3s + 1}$$

The controller is selected to be in the form

$$C(s) = 10 + Ks$$

and the value of K is to be determined based on the desired damping ratio for the unity feedback system.

a. Explain why we anticipate non-zero steady-state error when the closed-loop system responds to a step change in the reference. Is the error reduced by choosing a large value for K? **(4 marks)**

b. Determine the closed-loop transfer function, assuming unity feedback. **(8 marks)**

c. Find the required value of K so the closed-loop system has a damping ratio $\zeta = 0.55$. **(5 marks)**

d. Determine the expected overshoot and 5% settling time in this case. **(5 marks)**

e. State how the control engineer might attempt to reduce the settling time without increasing overshoot. **(3 marks)**