[ENG71]

UNIVERSITY OF GREATER MANCHESTER

SCHOOL OF ENGINEERING

B.ENG (HONS) ELECTRICAL AND ELECTRONIC ENGINEERING

SEMESTER 2 EXAMINATIONS 2024/2025

INSTRUCTIONS AND CONTROL

MODULE NO: EEE5011

Date: Wednesday 14 May 2025 **Time: 14:00 - 16:30**

INSTRUCTIONS TO CANDIDATES:

There are SIX questions.

Answer ANY FOUR questions.

All questions carry equal marks.

Marks for parts of questions are shown in brackets.

Electronic calculators may be used provided that data and program storage memory is cleared prior to the examination.

CANDIDATES REQUIRE: **Formula Sheet (attached).**

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Question 1

(a) A second order system has the following transfer function:

$$\frac{200}{s^2 + 12s + 400}$$

(i) Find the natural frequency ω_n, the damping ratio ζ and the damped frequency ω_d. **[6 marks]**

(ii) Calculate the peak time and rise time for the system, and estimate the 2% settling time, both to three significant figures. **[6 marks]**

(iii) Calculate the percentage overshoot for the system. **[3 marks]**

(b) A first order system has steady state value 8 and time constant 0.25 seconds.

Find the transfer function of the system.

Calculate the response of the system to a unit step input.

Find the value of the output after 0.8 seconds, to two decimal places.

[10 marks]

Total 25 marks

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Question 2

(a) Consider the system block diagram shown in Figure 2a.

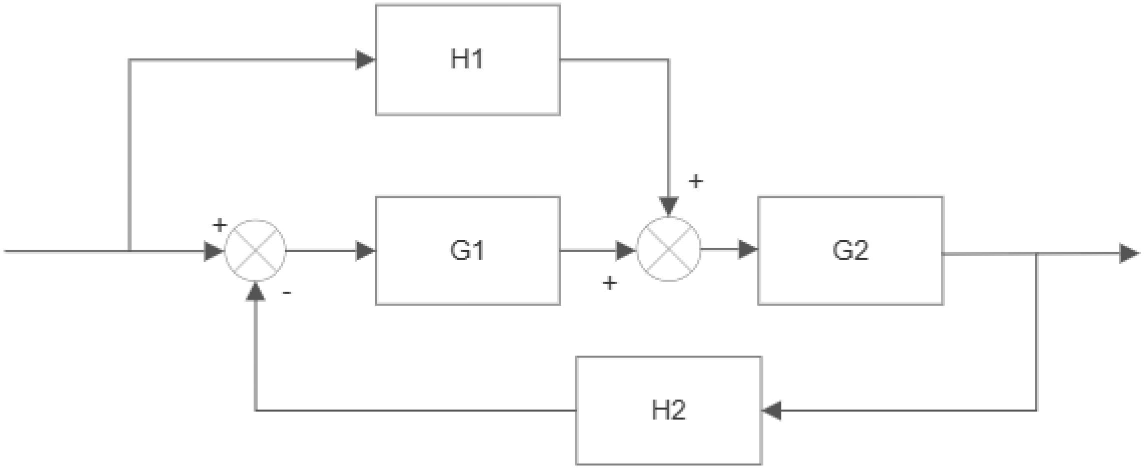

Figure 2a

By applying the rules for block reduction, find the transfer function to represent this system as a single block.

[15 marks]

(b) Consider the system block diagram shown in Figure 2b.

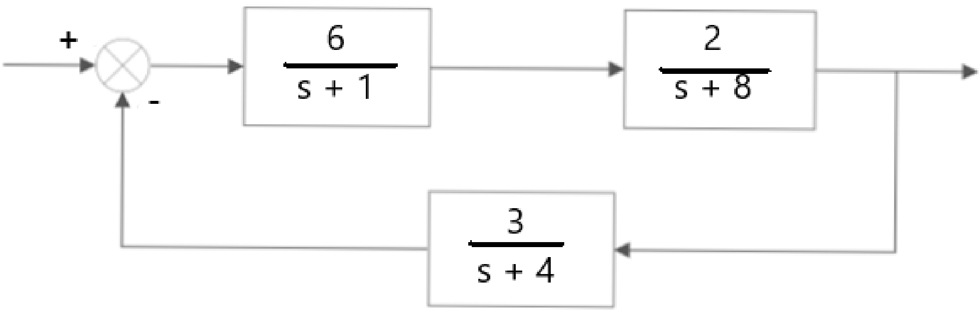

Figure 2b

Calculate and simplify the closed loop transfer function for the system.

State, with reasons, whether or not the system is stable.

[10 marks]

Total 25 marks

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Question 3

Consider the control system shown in figure 3:

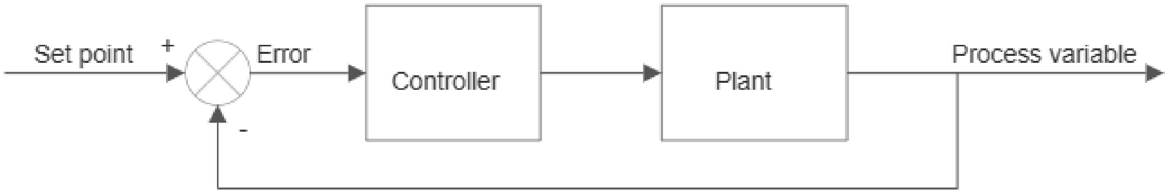

Figure 3

The controller is an proportional controller with gain K, and the plant is

$$\frac{20}{s^2 + 8s + 10}$$

and the system uses unity negative feedback. We wish to design the controller so that the overshoot does not exceed 16% and the steady state error for a unit step input does not exceed 0.1.

(i) Write down the open loop transfer function of the system. **[2 marks]**

(ii) Find an expression for the steady state error for unit step input in terms of K. **[4 marks]**

(iii) Find the range of values for K for which the steady state error does not exceed 0.1. **[3 marks]**

(iv) Find the closed loop transfer function of the system. **[4 marks]**

(v) Find expressions for the natural frequency and the damping ratio in terms of K. **[5 marks]**

(vi) Find the value of the damping ratio that gives an overshoot of 16%. **[3 marks]**

(vii) Find the range of values for K for which the overshoot does not exceed 16%. **[4 marks]**

Total 25 marks

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Question 4

(a) Consider the control system with disturbance shown in figure 4a

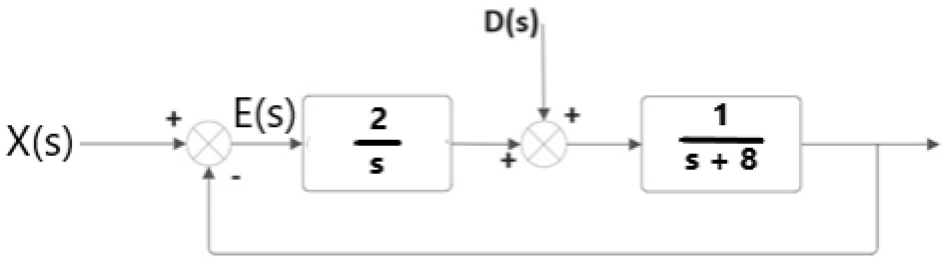

Figure 4a

Find an expression for the error $E(s)$ in terms of the input $X(s)$ and the disturbance signal $D(s)$. **[8 marks]**

If the input is a unit ramp, and the disturbance is a step of size 10, find the value of the steady state error. **[7 marks]**

(b) Consider the control system shown in figure 4b.

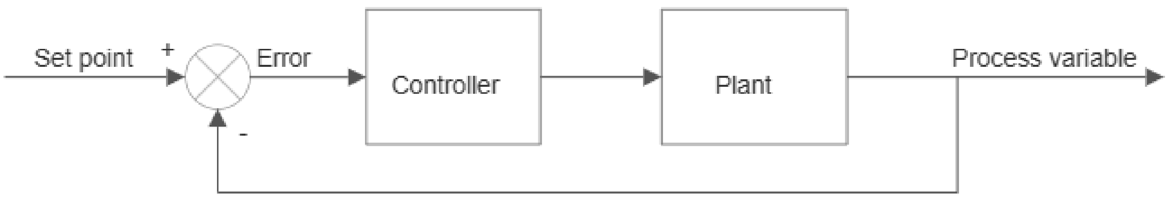

Figure 4b

The controller is an proportional controller K, and the plant is

$$G(s) = \frac{5}{s^3 + 8s^2 + 6s + 3}$$

(i) Find the closed loop transfer function for the system. **[6 marks]**

(ii) Find the range of values for K for which the system is stable. **[4 marks]**

Total 25 marks

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Question 5

Consider the buck converter shown in Figure 5

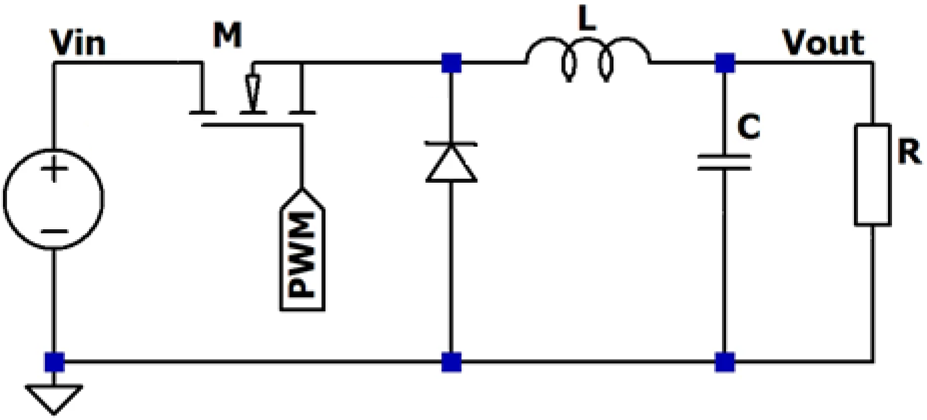

Figure 5 Buck Converter circuit diagram

Using Kirchhoff's laws, find the mathematical relationship between output voltage and the input voltage

[16 marks]

and find:

(i) The transfer function $\frac{V_{out}(s)}{V_{in}(s)}$

[4 marks]

(ii) The undamped natural frequency if R=1.0 Ohm, L=0.1 H, C=100mF

[5 marks]

You may ignore the internal resistances of both the inductance and the capacitance.

Total 25 marks

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Question 6

(a) What are the main types of biomedical measurands? **[5 marks]**

(b) Define three of the following static characteristics of a medical instrument**:**

(i) Reference value
(ii) Resolution
(iii) Precision
(iv) Accuracy **[6 marks]**

(c) List three features that a medical measurement equipment should demonstrate regardless of the nature of data measured. **[6 marks]**

(d) Explain the function of an inductive proximity sensor using the parameters of the inductance formula $= \frac{\mu_o \mu_r N^2 A}{l}$. Illustrate your answer with the help of diagrams.

[8 marks]

Total 25 marks

END OF QUESTIONS

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FORMULA SHEET

Parameters of second order systems

Relation between ω_n, ω_d and ζ:

$$\omega_d = \sqrt{1-\zeta^2}\omega_n \qquad \omega_n = \frac{1}{\sqrt{1-\zeta^2}}\omega_d \qquad \zeta = \sqrt{1-\left(\frac{\omega_d}{\omega_n}\right)^2}$$

Relation between damping ratio and percentage overshoot:

$$overshoot = 100exp\left(-\frac{\zeta\pi}{\sqrt{1-\zeta^2}}\right) \qquad \zeta = \sqrt{\frac{(\ln A)^2}{\pi^2+(\ln A)^2}}$$

Rise time, peak time, and 5% and 2% settling times:

$$t_{rise} = \frac{\pi-\phi}{\omega_d} \text{ where } \phi = \cos^{-1}(\zeta) \qquad t_{peak} = \frac{\pi}{\omega_d}$$

$$t_{settle,5\%} \approx \frac{3}{\zeta\omega_n} \qquad t_{settle,2\%} \approx \frac{4}{\zeta\omega_n}$$

Table of Laplace Transforms

$\boldsymbol{f(t)}$	$\boldsymbol{F(s) = \int_0^\infty f(t)e^{-st}dt}$
1	$\frac{1}{s}$
t	$\frac{1}{s^2}$
e^{-at}	$\frac{1}{s+a}$
$\sin\omega t$	$\frac{\omega}{s^2+\omega^2}$
$\cos\omega t$	$\frac{s}{s^2+\omega^2}$
$e^{-at}f(t)$	$F(s+a)$
$f'(t)$	$sF(s)-f(0)$

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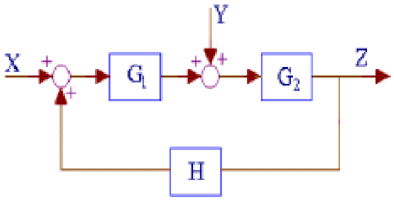
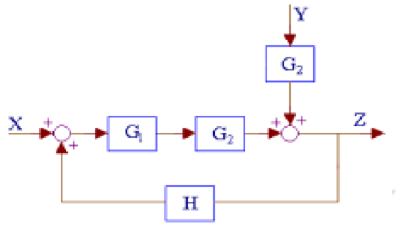
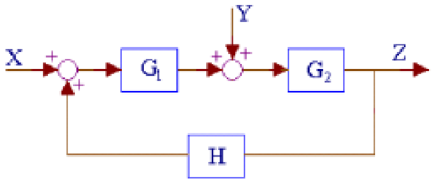
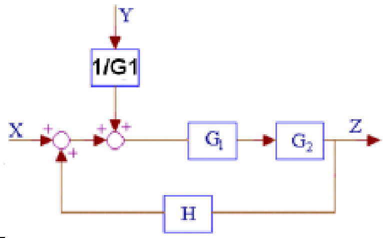
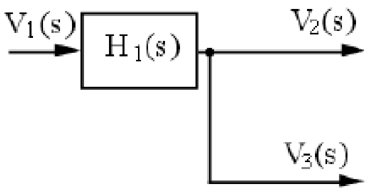
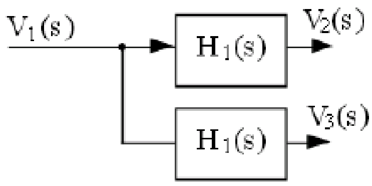
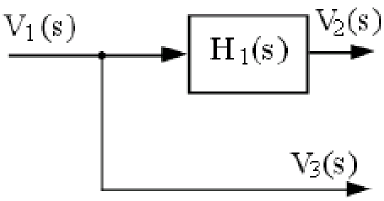
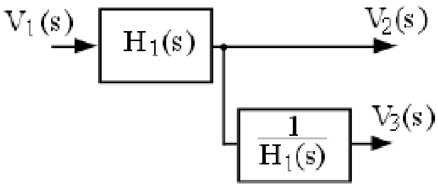
Block diagrams

Rule	Original Diagram	Equivalent Diagram
1. Moving a summing point beyond a block		
2. Moving a summing point in front a block		
3. Moving a takeoff point to front of a block		
4. Moving a takeoff point to beyond a block		

Blocks with feedback

$G(s)$ is forward path, $H(s)$ is feedback path.

Negative feedback: $$\frac{G(s)}{1+G(s)H(s)}$$

Positive feedback: $$\frac{G(s)}{1-G(s)H(s)}$$

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