UNIVERSITY OF BOLTON

SCHOOL OF ENGINEERING

BENG (HONS) BIOMEDICAL ENGINEERING

SEMESTER 2 EXAMINATIONS 2021/2022

MEDICAL INSTRUMENTATION & CONTROL

MODULE NO: BME5002

Date: Tuesday 17th May 2022 **Time: 10.00 - 12.00**

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:

A formula sheet is included.

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Question 1

(a-i) Determine the location of closed loop pole **[10 marks]**

$$\frac{C(S)}{R(S)} = \frac{20}{(S+6)(S+8)}$$

(a-ii) Determine the stability of the system **[6 marks]**

(b) Show the in between the three step inputs highlighting their wave forms, physical interpretation, and time functions. **[9 marks]**

Total 25 marks

Question 2

(a) Sketch the block diagram of a bio-telemetry system **[10 marks]**

(b) Mention 5 types of sensors used in biomedical instruments? **[5 marks]**

(c) Define briefly each one of the following:

i. Precision **[2 marks]**
ii. Accuracy **[2 marks]**
iii. Resolution **[2 marks]**

(d) Highlight 4 of the important considerations necessary for selecting a transducer. **[4 marks]**

Total 25 marks

Question 3

a) The open-loop transfer function of a system is $G(s) = \frac{K}{s(s+7)(s+8)}$.

Determine the value of K which will cause sustained oscillations in the closed loop unity feedback system. You can use Routh-Hurwitz criterion.

[10 marks]

b) What is the steady-state error of the system whose open-loop transfer function is $G(s) = \frac{K}{s(s+2)(s+8)}$ for a unit step input, ramp input and what is its type?

[15 marks]

Total 25 marks

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Question 4

Consider the control system shown in Fig.1 with its closed loop form.

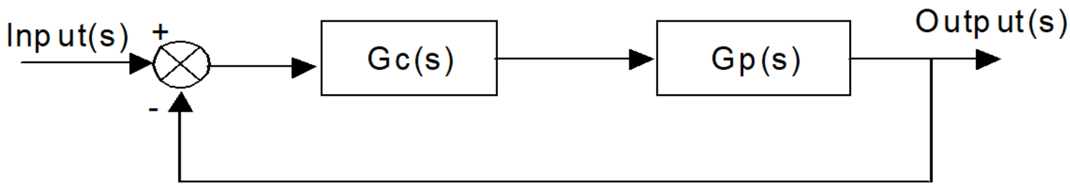

Fig.1

where $G_P(s) = \frac{1}{s(s^2+7s+12)}$

a) If Gc(s) is a proportional controller (Ki = Kd = 0), find the range of the gain Kp making the system to be an underdamped system. **[7 Marks]**

b) Find the Ki for a unit ramp input ($\frac{1}{s^2}$) if Gc(s) is a PI controller and the steady state error is less than 0.01. **[9 marks]**

c) The designer needs to achieve less than 20% overshoot and t_s less than 5 seconds. Design a PID controller by determining Kp and Kd (using the Ki obtained from Question 4 (b) above) to satisfy these requirements. **[9 marks]**

Total 25 marks

Question 5

a) A unity feedback system is characterized by an open-loop transfer function

$$G(s) = \frac{K}{s(s+8)}$$

(i) Determine the gain K so that the system have a damping ratio of 0.7 **[4 marks]**

(ii) For the value of K obtained in (a) and a unit step input, determine:

1- settling time **[4 marks]**
2- peak overshoot **[4 marks]**
3- time to peak overshoot **[4 marks]**

b) Obtain the y(t) solution of the given Laplace transform making use of the Laplace transform table and the partial fraction method. **[9 marks]**

$$\frac{(s+10)}{(s+5)(s+7)}$$

Total 25 marks

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Question 6

(a) For the system shown in Fig.2 below, obtain:

(i) the transfer function $\frac{Y(s)}{U(s)}$ **[9 marks]**

(ii) the damping factor **[3 marks]**

(iii) the undamped natural angular frequency **[3 marks]**

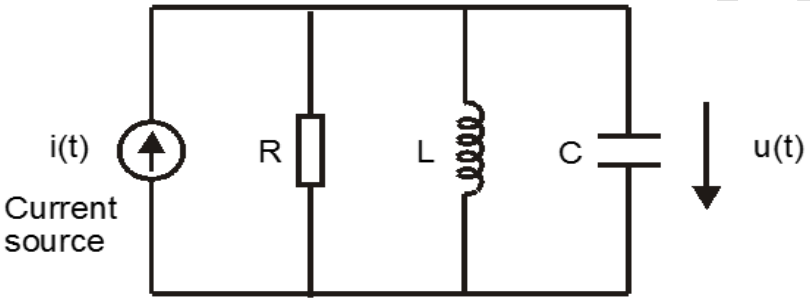

Fig. 2 parallel RLC circuit

Where R = 5.0 Ohms, L = 100 mH, C = 10 mF

(b) Derive the transfer function $\frac{C(S)}{R(S)}$ of the system shown in Fig. 3. **[10 marks]**

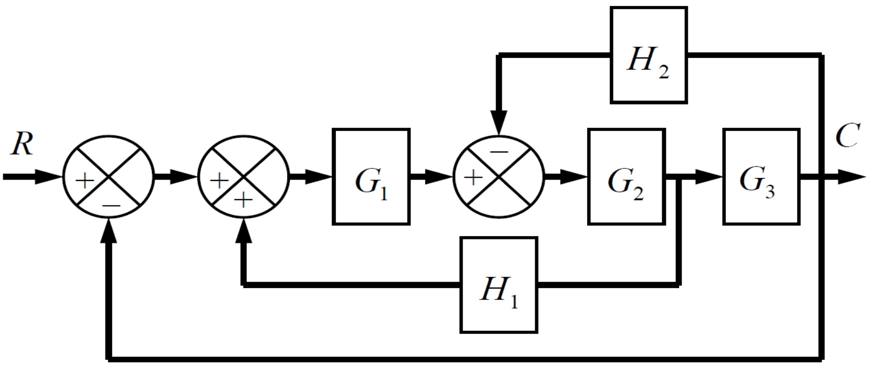

Fig. 3

Total 25 marks

END OF QUESTIONS

Formula sheet follows over the page

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FORMULAE TABLE

These equations are given to save short-term memorisation of details of derived equations and are given without any explanation or definition of symbols; the student is expected to know the meanings and usage.

The Laplace Transform

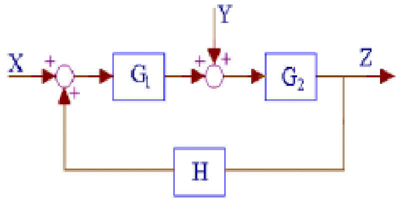
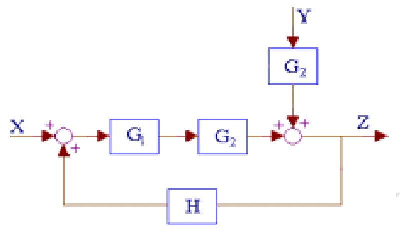
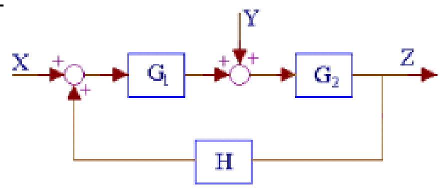
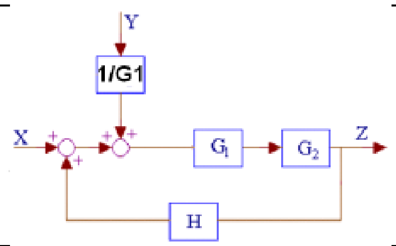
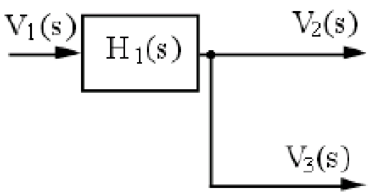
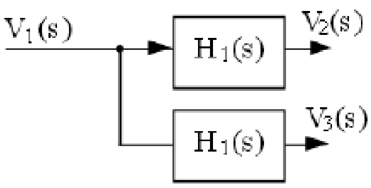
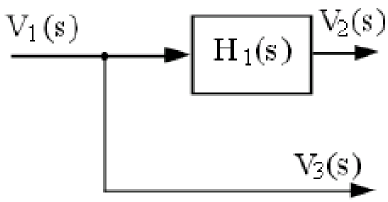
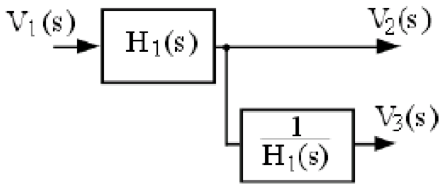
Transform table:

	$f(t)$	$F(s)$	
1.	$\delta(t)$	1	Impulse function
2.	$u(t)$	$\frac{1}{s}$	Step function
3.	$t\,u(t)$	$\frac{1}{s^2}$	Ramp function
4.	$t^n\,u(t)$	$\frac{n!}{s^{n+1}}$	
5.	$e^{-at}\,u(t)$	$\frac{1}{s+a}$	
6.	$\sin \omega t\, u(t)$	$\frac{\omega}{s^2+\omega^2}$	
7.	$\cos \omega t\, u(t)$	$\frac{s}{s^2+\omega^2}$	

	$f(t)$	$F(s)$
	$df(t)/dt$	$sF(s)-f(0)$
	$d^2f(t)/dt^2$	$s^2F(s)-sf(0)-f'(0)$

$$M_p = e^{\frac{-\xi\pi}{\sqrt{1-\xi^2}}}, \quad t_p = \frac{\pi}{\omega_n\sqrt{1-\xi^2}}, \quad t_s = \frac{4}{\xi\omega_n}$$

Block Diagram Algebra

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 Loop

$$G(s) = \frac{Go(s)}{1+Go(s)H(s)}$$ (for a negative feedback)

$$G(s) = \frac{Go(s)}{1-Go(s)H(s)}$$ (for a positive feedback)

Please turn the page…

Steady State Error

$$e_{ss} = \lim_{s\to 0}[s(1 - G_O(s))\theta_i(s)]$$ (for an open-loop system)

$$e_{ss} = \lim_{s\to 0}[s\frac{1}{1+G_o(s)}\theta_i(s)]$$ (for the closed-loop system with a unity feedback)

$$e_{ss} = \lim_{s\to 0}[s\frac{1}{1+\frac{G_1(s)}{1+G_1(s)[H(s)-1]}}\theta_i(s)]$$ (if the feedback H(s) ≠ 1)

$$e_{ss} = \lim_{s\to 0}[-s\cdot\frac{G_2(s)}{1+G_2(G_1(s)+1)}\cdot\theta_d]$$ (if the system subjects to a disturbance input)

First Order System

$$G(s) = \frac{\theta_o}{\theta_i} = \frac{G_{ss}(s)}{\tau s+1}$$

$$\tau\left(\frac{d\theta_o}{dt}\right) + \theta_o = G_{ss}\theta_i$$

$$\theta_O = G_{ss}(1 - e^{-t/\tau})$$ (for a unit step input)

$$\theta_o(t) = G_{ss}[t - \tau(1 - e^{-(t/\tau)})]$$ (for a unit ramp input)

$$\theta_o(t) = G_{ss}(\frac{1}{\tau})e^{-(t/\tau)}$$ (for an impulse input)

END OF PAPER