Universiti Tun Hussein Onn Malaysia

UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER II
SESSION 2023/2024

COURSE NAME	:	CONTROL SYSTEM
COURSE CODE	:	DAE 32103
PROGRAMME CODE	:	DAE
EXAMINATION DATE	:	JULY 2024
DURATION	:	3 HOURS
INSTRUCTIONS	:	1. ANSWER ALL QUESTIONS 2. THIS FINAL EXAMINATION IS CONDUCTED VIA ☐ Open book ☒ Closed book 3. STUDENTS ARE **PROHIBITED** TO CONSULT THEIR OWN MATERIAL OR ANY EXTERNAL RESOURCES DURING THE EXAMINATION CONDUCTED VIA CLOSED BOOK

THIS QUESTION PAPER CONSISTS OF **EIGHT (8)** PAGES

Q1 Control System can be defined as an interconnection of components forming a system configuration that will provide a desired system response. There are two (2) main types of control system which are open loop and closed loop.

(a) A ceiling fan control system is an example of open loop system. Describe in detail how to convert the system into closed loop system.

(4 marks)

(b) Clarify three (3) reasons for using feedback control system and at least one (1) reason for not using the system.

(8 marks)

(c) **Figure Q1.1** shows a wastewater treatment control system.

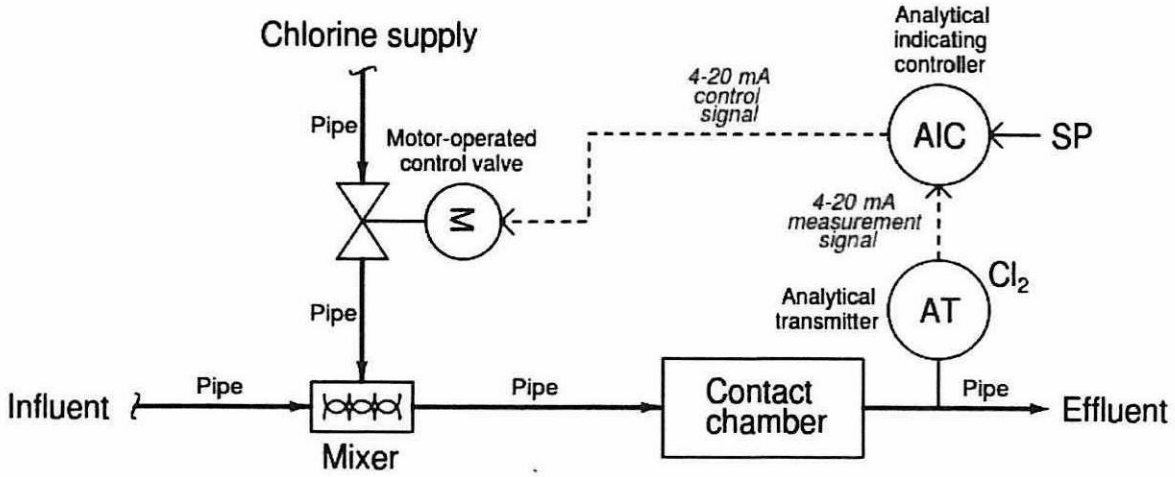

Figure Q1.1 A Wastewater Treatment Control System

(i) Determine the controlled variable, manipulated variable and plant of the system.

(3 marks)

(ii) Draw the complete block diagram of the control system.

(6 marks)

(iii) Briefly discuss two (2) examples of disturbance that could affect the control system.

(4 marks)

Q2 Transfer function can be defined as ratio of the output to the input; with all initial conditions are zero.

(a) For each of the following transfer function, find the corresponding differential equation.

(i) $\frac{X(s)}{F(s)} = \frac{1}{s^2+2s+7}$

(4 marks)

(ii) $\frac{X(s)}{F(s)} = \frac{s+2}{s^3+8s^2+9s+15}$

(4 marks)

(b) State three (3) types of time domain input function together with their respective s-domain equation.

(3 marks)

(c) Discover the transfer function $G(s) = \frac{I_2(s)}{V(s)}$ for the following RLC network using Mesh analysis. Given that the value of $R_1 = R_2 = 1\Omega$ meanwhile L = 1H and C= 1F as shown in **Figure Q2.1**.

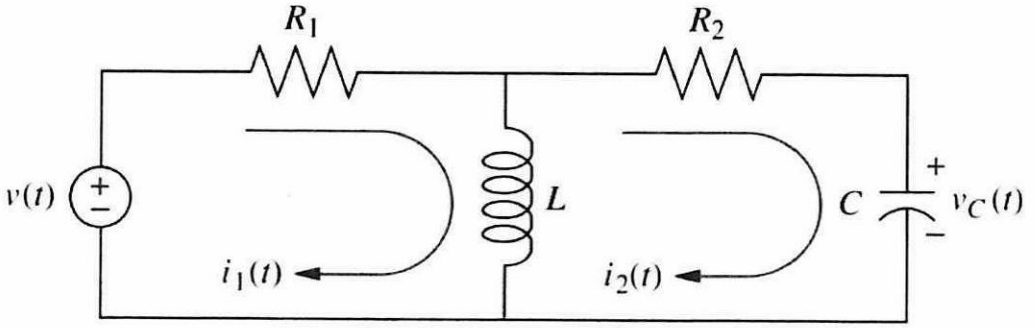

Figure Q2.1 A RLC Network Circuit

(7 marks)

(d) A second order control system with unity feedback has a damping ratio of 0.4 and natural frequency of 12 rad/s.

(i) Write down the closed loop transfer function for the system.

(3 marks)

(ii) Determine the stability of the system.

(4 marks)

Q3 There are many research and investigation on the stability of second-order system due to the complexity and multiplicity of the system.

(a) Briefly discuss the differences of the four (4) types of step responses in second order system.

(8 marks)

(b) Describe the effects of poles position to the stability of a control system.

(2 marks)

(c) **Figure Q3.1** shows a time response for a second order system.

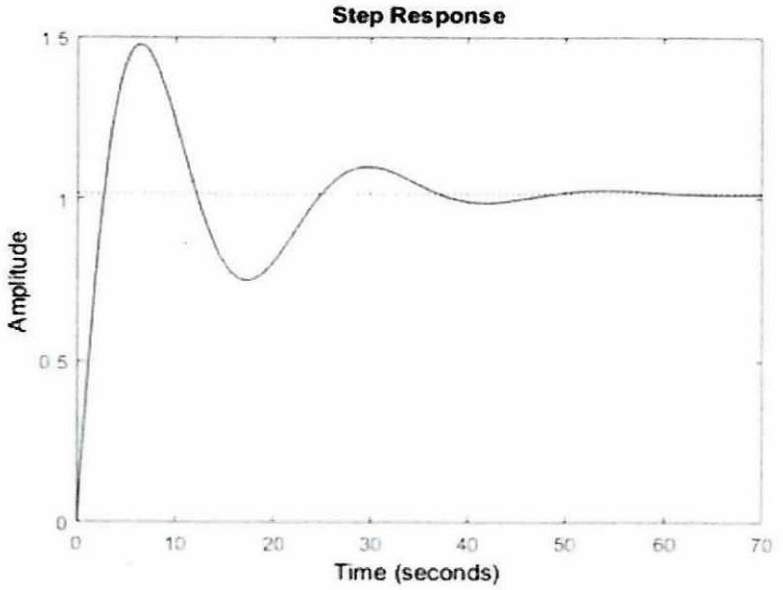

Figure Q3.1 A Time Response for A Second Order System

(i) Redraw and label the overshoot, rise time, peak time, settling time and steady state error on **Figure Q3.1**.

(5 marks)

(ii) Explain the effects of implementing a Proportional Integral Controller (PID) in the system of **Figure Q3.1**.

(6 marks)

(d) Analog to Digital Converter (ADC) and Digital to Analog Converter (DAC) are very important in digital control system. Determine the number of bits a DAC converter must have to provide an output increment of 0.04 V. The reference voltage is 10 V.

(4 marks)

Q4 In any control system, the process control will force a physical variable to remain constant in time and equal to some desired value.

(a) List two (2) types of measurement in process control.

(2 marks)

(b) Describe the working concept of two (2) types of process control.

(4 marks)

(c) There are a few variables involved in process control. Explain the following terminologies applied in process control.

(i) Set Point.

(1 mark)

(ii) Manipulated Variable.

(1 mark)

(iii) Controlled Variable.

(1 mark)

(iv) Disturbance Variable.

(1 mark)

(d) **Figure Q4.1** shows unity feedback system use by Usaha Jaya Sdn. Bhd. for controlling temperature of steam distillation process. For improvement, the company plan to implement PID controller for controlling the temperature of the process.

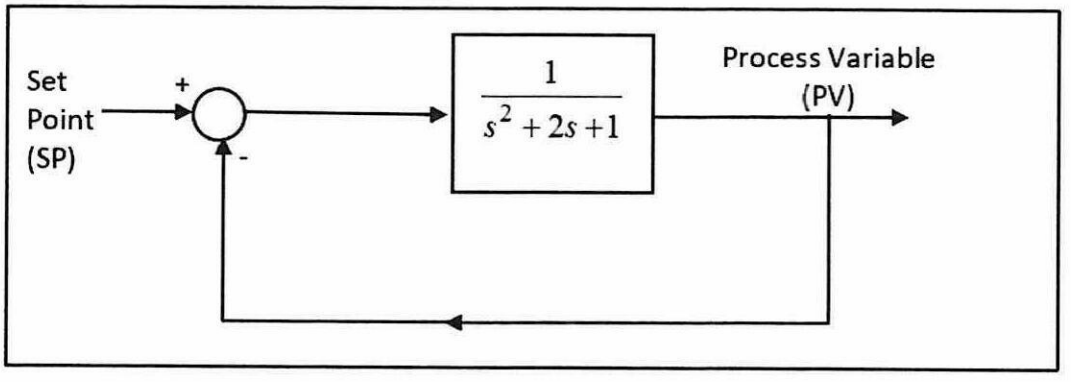

Figure Q4.1 A Temperature Controlling System

(i) Sketch PID controller block diagram for the system when the parameters of the controller will be implemented as given:

Proportional, $K_p = 5$
Integral, $K_i = 1$
Derivative, $K_d = 2$

(5 marks)

(ii) Based on the block diagram sketch in **Q4(d)(i)**, solve the closed loop transfer function for the system.

(6 marks)

(iii) If the Set Point (SP) = 85 °C and Process Variable (PV) = 79 °C, interpret the operation of the system.

(4 marks)

- END OF QUESTIONS -

APPENDIX A

Laplace Transform Table

S.no	$f(t)$	$\mathcal{L}\{f(t)\}$	S.no	$f(t)$	$\mathcal{L}\{f(t)\}$
1	1	$\frac{1}{s}$	11	$e^{at}\sinh bt$	$\frac{b}{(s-a)^2-b^2}$
2	e^{at}	$\frac{1}{s-a}$	12	$e^{at}\cosh bt$	$\frac{s-a}{(s-a)^2-b^2}$
3	t^n	$\frac{n!}{s^{n+1}}$	13	$t\cos at$	$\frac{s^2-a^2}{(s^2+a^2)^2}$
4	$\sin at$	$\frac{a}{s^2+a^2}$	14	$t\sin at$	$\frac{2as}{(s^2+a^2)^2}$
5	$\cos at$	$\frac{s}{s^2+a^2}$	15	$f'(t)$	$sF(s)-f(0)$
6	$\sinh at$	$\frac{a}{s^2-a^2}$	16	$f''(t)$	$s^2F(s)-sf(0)-f'(0)$
7	$\cosh at$	$\frac{s}{s^2-a^2}$	17	$\int_0^t f(u)du$	$\frac{1}{s}F(s)$
8	$e^{at}t^n$	$\frac{n!}{(s-a)^{n+1}}$	18	$t^nf(t)$ Where $n=1,2,3,..$	$(-1)^n\frac{d^n}{ds^n}\{F(s)\}$
9	$e^{at}\cos bt$	$\frac{s-a}{(s-a)^2+b^2}$	19	$\frac{1}{t}\{f(t)\}$	$\int_s^\infty F(s)ds$
10	$e^{at}\sin bt$	$\frac{b}{(s-a)^2+b^2}$	20	$e^{at}f(t)$	$F(s-a)$

APPENDIX B

Electrical Network Transfer Function

Component	Voltage-current	Current-voltage	Voltage-charge	Impedance $Z(s) = V(s)/I(s)$	Admittance $Y(s) = I(s)/V(s)$
Capacitor	$v(t)=\frac{1}{C}\int_0^t i(\tau)\,d\tau$	$i(t)=C\frac{dv(t)}{dt}$	$v(t)=\frac{1}{C}q(t)$	$\frac{1}{Cs}$	Cs
Resistor	$v(t)=Ri(t)$	$i(t)=\frac{1}{R}v(t)$	$v(t)=R\frac{dq(t)}{dt}$	R	$\frac{1}{R}=G$
Inductor	$v(t)=L\frac{di(t)}{dt}$	$i(t)=\frac{1}{L}\int_0^t v(\tau)d\tau$	$v(t)=L\frac{d^2q(t)}{dt^2}$	Ls	$\frac{1}{Ls}$

APPENDIX C

Formula for Underdamped Second Order System

$$t_p = \frac{\pi}{\omega_n\sqrt{1-\zeta^2}} = \frac{\pi}{\omega_d}$$

$$M_p = e^{\frac{-\zeta\pi}{\sqrt{1-\zeta^2}}}$$

$$\%M_p = e^{\frac{-\zeta\pi}{\sqrt{1-\zeta^2}}} \times 100\%$$

$$t_r = \frac{\pi - \cos^{-1}\zeta}{\omega_n\sqrt{1-\zeta^2}}$$

$$T_s = \frac{4}{\zeta\omega_n} \text{ (2\% criterion)}$$

$$T_s = \frac{3}{\zeta\omega_n} \text{ (5\% criterion)}$$