Universiti Tun Hussein Onn Malaysia

UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER II
SESSION 2023/2024

COURSE NAME	:	PROCESS CONTROL SYSTEMS
COURSE CODE	:	BEJ44603
PROGRAMME CODE	:	BEJ
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 (a) Describe what is process control.

(2 marks)

(b) List at least **FOUR (4)** industries that applied process control.

(4 marks)

(c) Describes the definition of following process control systems components:

(i) Sensor.

(2 marks)

(ii) Final Control Elements.

(2 marks)

(d) The Piping and Instrumentation Diagram (P&ID) for controlling water level of the tank by controlling water output used by ManirWater Sdn. Bhd is as shown in **Figure Q1.1** where:

LC = Level Controller.

FC = Flow Controller.

LT = Level Transmitter.

FT = Flow Transmitter.

LV = Level Valve.

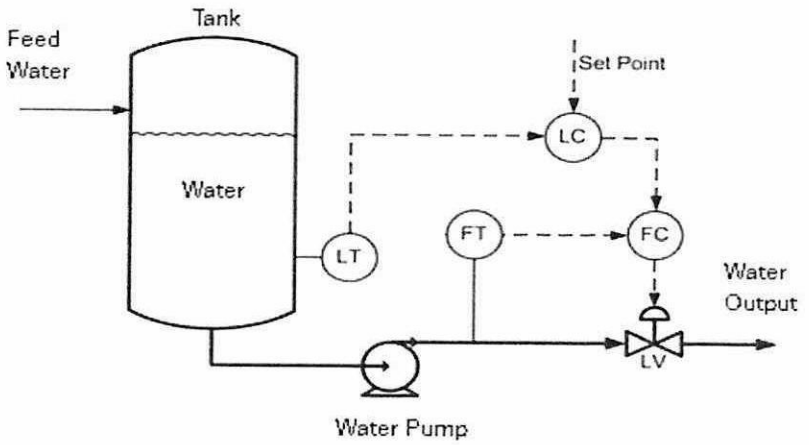

Figure Q1.1 : Water level Piping and Instrumentation Diagram (P&ID).

(i) Point out the type of control structure used by the system.

(2 marks)

(ii) Establish the block diagram of the system.

(10 marks)

(iii) Examine the function of Level Controller (LC) and Flow Transmitter (FT).

(3 marks)

Q2 (a) List at least **THREE (3)** types of flow measurement method in process control.

(3 marks)

(b) Based on **Figure Q2.1,** explain the operation of bourdon tube for pressure measurement.

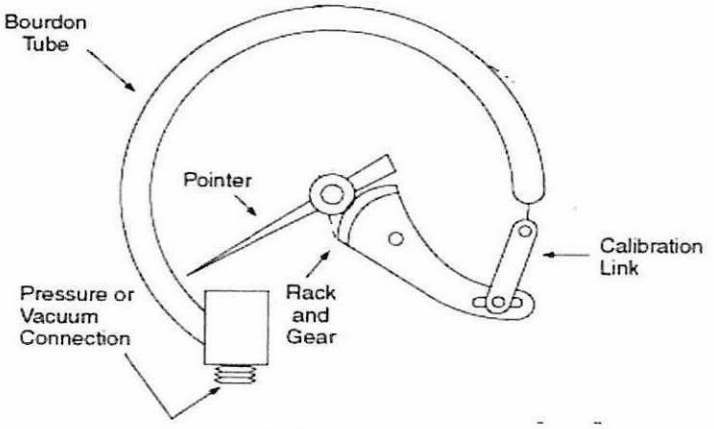

Figure Q2.1: Bourdon Tube.

(3 marks)

(c) The system used by SirapMerah Sdn. Bhd. for maintained closed tank liquid level using dry leg method is illustrated in **Figure Q2.2.** Given that the **H1**=200 cm and weight density of the liquid, S = 7000 N/m^3.

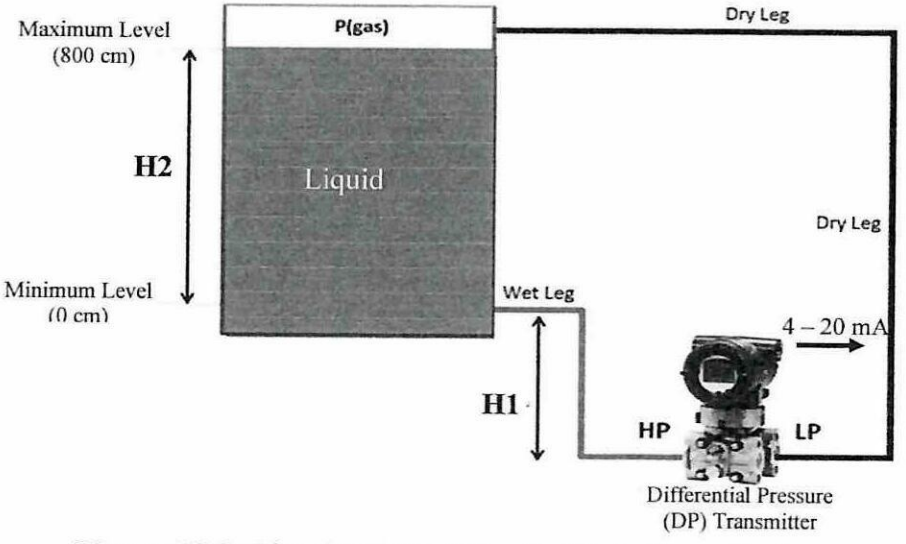

Figure Q2.2: Closed tank liquid level with dry leg method.

(i) Determine the electrical signal produce by Differential Pressure (DP) transmitter when **H2** is at 700 cm.

(6.5 marks)

(ii) Determine the **H2** when pressure measured by DP is equal to 40,000 Pascals.

(7 marks)

(d) The venturi tube shown in **Figure Q2.3** is used by SawitOil Holding to measure the speed of a oil fluid in a pipe. Given that:

Cross-sectional areas at point $A_2 = 188\ cm^2$.

Liquid speed at $V_1 = 7.2$ m/s.

Fluid density, $\rho = 10\ kg/m^3$.

Volumetric flowrate, $Q_v = 0.15\ m^3/s$.

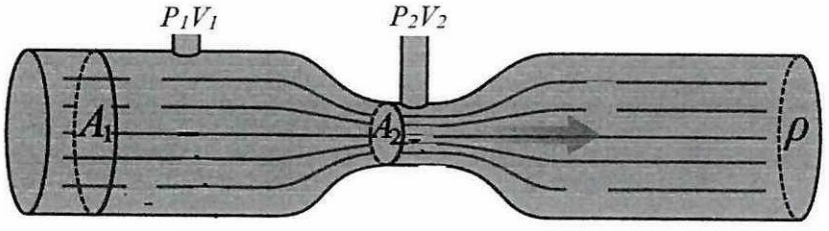

Figure Q2.3: Venturi tube.

Calculate:

(i) The fluid speed at V_2.

(2 marks)

(ii) The cross-sectional area at point A_1.

(1.5 marks)

(ii) The Pressure Difference.

(2 marks)

Q3 (a) PowerOil Sdn. Bhd. plan to use Feedforwards controller for controlling temperature of its heat exchanger system. Given that:

Heat exchanger transfer function, $G_p(s) = \dfrac{7e^{-25s}}{6s+1}$

Disturbances transfer function, $G_d(s) = \dfrac{9e^{-25s}}{(6s+1)(2s+1)}$

(i) Calculate the Feedforward gain for the system.

(2 marks)

(ii) If the system has Controller Gain $(G_c(s)) = \left(2 + \dfrac{1}{50s} + 0.5s\right)$, Valve Gain $(G_v(s)) = 0.5$, Feedforward Sensor Gain $(G_{ffs}(s)) = 2$, Feedback Sensor Gain $(G_{fbs}(s)) = 1$, construct the Feedforward block diagram for the system.

(7 marks)

(b) The plot of input and output open loop experimental data for herb drying systems is shown in **Figure Q3.1**.

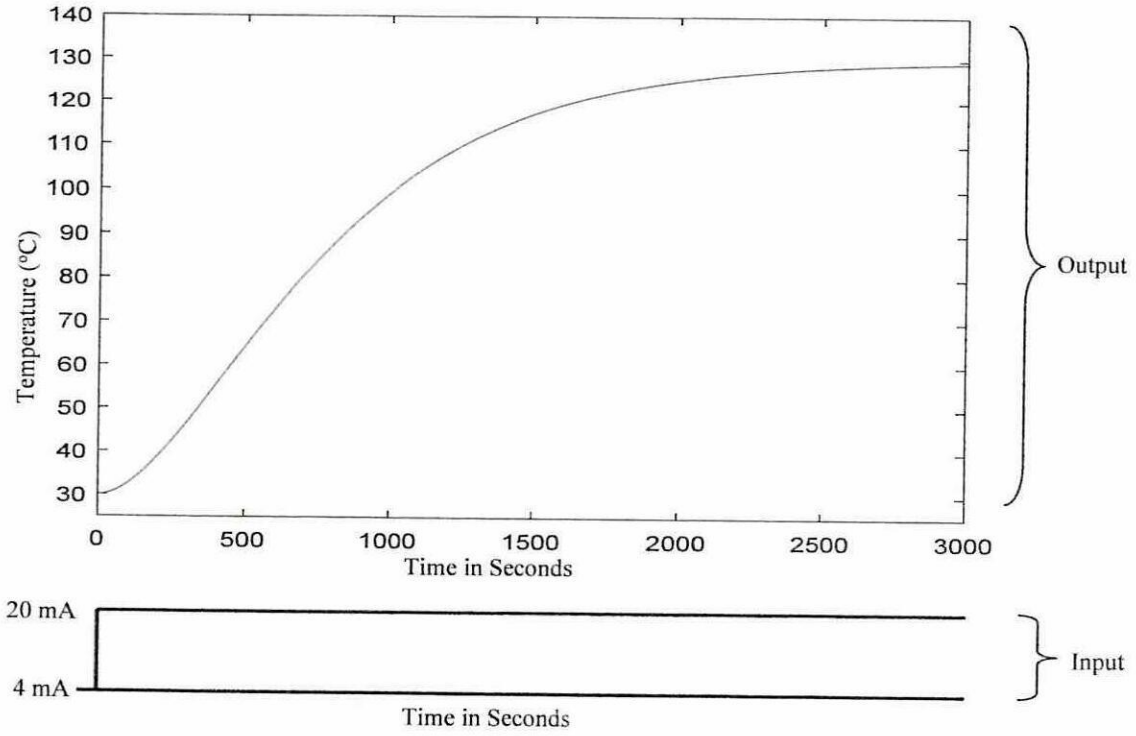

Figure Q3.1: Herb drying input and output experimental data.

(i) List at least **FOUR (4)** steps for developing First Order Plus Dead Time (FOPDT) Model.

(4 marks)

(ii) Estimate the FOPDT model for the system.

(12 marks)

Q4 (a) The heating process system for oil bleaching is controlled by an on-off controller. When the heater is on the temperature rises at 0.7 Celsius per minute. When the heater is off, the temperature drop at 0.4 Celsius per minute. The Set Point (SP) is at 90 Celsius and the neutral zone is ±5 Celsius of the set point. There is a 2.5 min lag at the on and off switch points.

(i) Describe the function of neutral zone in on-off controller.

(2 marks)

(ii) Established the response of on-off controller for the system.

(7 marks)

(iii) Calculate the period of oscillation for the system.

(5 marks)

(b) TinggiSolution Sdn. Bhd. has proposed **TWO (2)** sets of tuning parameters for a Proportional Integral (PI) controller namely Tune A and Tune B to the LakuOil Holding for controlling temperature of steam distillation system handled by the company. The response for both PI tuning (Tune A and Tune B) in controlling temperature of steam distillation system is shown in **Figure Q4.1**

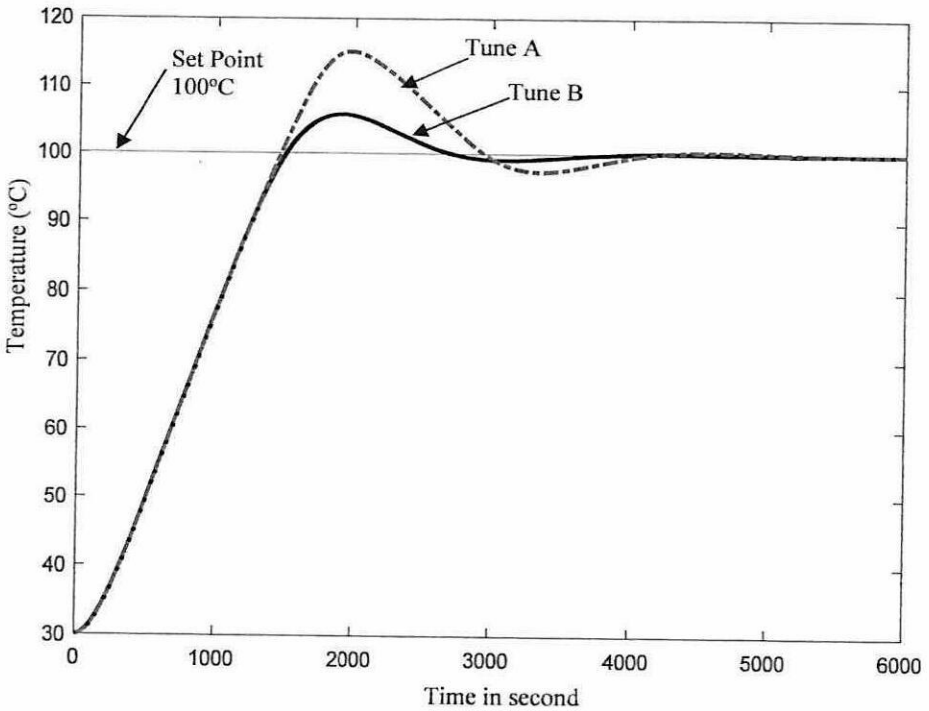

Figure Q4.1: Response Tune A and Tune B.

(i) By using transient analysis of 2% band, find settling time for each of the responses.

(9 marks)

(ii) LakuOil Holding has been set the performance specification for temperature regulation of steam distillation system as follow:

Settling time, Ts < 3300 second.

Based on answer **Q4b(i)**, examine the tuning that should be select by LakuOil Holding and highlight the reason of the selection.

(2 marks)

- END OF QUESTIONS –

APPENDIX A (FORMULAS)

Table A
Cohen Coon Tuning Formulae

Controller	K_p	T_i	T_d
P	$\frac{\tau}{K\theta}\left(1+\frac{\theta}{3\tau}\right)$		
PI	$\frac{\tau}{K\theta}\left(0.9+\frac{\theta}{12\tau}\right)$	$\theta\left(\frac{30+3\left(\frac{\theta}{\tau}\right)}{9+20\left(\frac{\theta}{\tau}\right)}\right)$	
PID	$\frac{\tau}{K\theta}\left(\frac{4}{3}+\frac{\theta}{4\tau}\right)$	$\theta\left(\frac{32+6\left(\frac{\theta}{\tau}\right)}{13+8\left(\frac{\theta}{\tau}\right)}\right)$	$\theta\left(\frac{4}{11+2\left(\frac{\theta}{\tau}\right)}\right)$

Table B
Process Model Equations

Model Name	Model Equation
FOPDT	$G(s)=\frac{Ke^{-\theta s}}{\tau s+1}$
SOPDT	$G(s)=\frac{Ke^{-\theta s}}{\tau^2 s^2+2\zeta\tau s+1}$

Table C
Steady State Analysis Formulae

MSE	$\frac{1}{n}\sum_{t=1}^{n} e_t^2$
RMSE	$\sqrt{\frac{1}{n}\sum_{t=1}^{n} e_t^2}$
ISE	$\int_0^{\infty}[e(t)]^2\,dt$
ITAE	$\int_0^{\infty} t\lvert e(t)\rvert dt$

Feedforwards Gain = $-\frac{G_d}{G_p}$

Bernoulli Equation

$$p_1 + \frac{1}{2}\rho v_1^2 = p_2 + \frac{1}{2}\rho v_2^2$$

where

$p = pressure\,(Pa, psi)$

$\rho = density\,(\mathrm{kg/m^3}, slugs/ft^3)$

$v = flow\ velocity\,(m/s, in/s)$

Assuming uniform velocity profiles in the upstream and downstream flow.

Therefore the Continuity Equation can be written as

$$Q_v = v_1 A_1 = v_2 A_2$$

Where :

A_1 is cross sectional area of pipe

A_2 is cross sectional area of orifice

Therefore

$$p_1 - p_2 = \frac{\rho}{2}(v_2^2 - v_1^2)$$

$$v_1 = \frac{A_2}{A_1} v_2$$

The volumetric flowrate

$$Q_v = A_2 V_2$$

$$Q_v = A_2 \sqrt{\frac{2(p_1 - p_2)}{\rho\left(1 - \frac{A_2^2}{A_1^2}\right)}}$$

Q_v in diameter form

$$Q_v = \frac{\pi}{4} d^2 \sqrt{\frac{2(p_1 - p_2)}{\rho\left(1 - \frac{d^4}{D^4}\right)}}$$

Mass Flowrate

$$Q_m = \rho Q_v = A_2 \sqrt{\frac{2(p_1 - p_2)\rho}{\left(1 - \frac{A_2^2}{A_1^2}\right)}} \text{ or } = \frac{\pi}{4} d^2 \sqrt{\frac{2(p_1 - p_2)\rho}{\left(1 - \frac{d^4}{D^4}\right)}}$$