Universiti Tun Hussein Onn Malaysia

UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
(TAKE HOME)
SEMESTER I
SESSION 2020/2021

COURSE NAME	:	PROCESS CONTROL
COURSE CODE	:	BNQ 30703
PROGRAMME	:	BNN
EXAMINATION DATE	:	JANUARY/FEBRUARY 2021
DURATION	:	3 HOURS
INSTRUCTION	:	ANSWER **ALL** QUESTIONS **OPEN BOOK EXAMINATION**

THIS QUESTION PAPER CONSISTS OF **SEVEN (7)** PAGES

Q1 (a) **Figure Q1(a)** shows a completely enclosed stirred-tank heating process is used to heat an incoming stream whose flow rate varies. The heating rate from this coil and the volume are both constant.

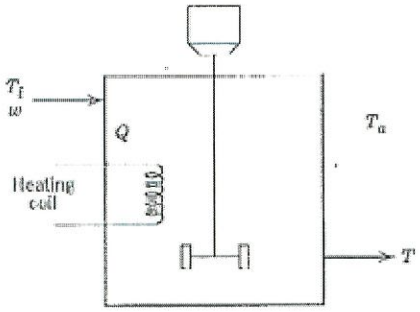

Figure Q1(a): Completely enclosed CSTR

Given;
ρ and C_p are constants
U = overall heat transfer coefficient, constant
A_s = surface area for heat losses to ambient
$T_i > T_a$ (inlet temperature is higher than ambient temperature)

(i) Based on **Figure Q1(a)**, develop a mathematical model (differential and algebraic equations) that describes the exit temperature if heat losses to the ambient occur and if the ambient temperature (T_a) and the incoming stream's temperature (T_i) both can vary.

(6 marks)

(ii) Discuss qualitatively your expectation when T_i and w increase (or decrease). Justify by reference to your model.

(4 marks)

(b) The liquid storage tank shown in **Figure Q1 (b)** has two inlet streams with mass flow rates w_1 and w_2 and an exit stream with flow rate w_3. The cylindrical tank is 2.5 m tall and 2 m in diameter. The liquid has a density of 800 kg/m^3. Normal operating procedure is to fill the tank until the liquid level reaches a nominal value of 1.75 m using constant flow rates: w^1 = 120 kg/min, w^2 = 100 kg/min, and w^3 = 200 kg/min. At that point, inlet flow rate w_1 is adjusted so that the level remains constant. However, on this particular day, corrosion of the tank has open up a hole in the wall at a height of 1 m, producing a leak whose volumetric flow rate q_4 (m^3/min) can be approximate by:

$$q_4 = 0.025\sqrt{h-1}$$

where h is height in meters.

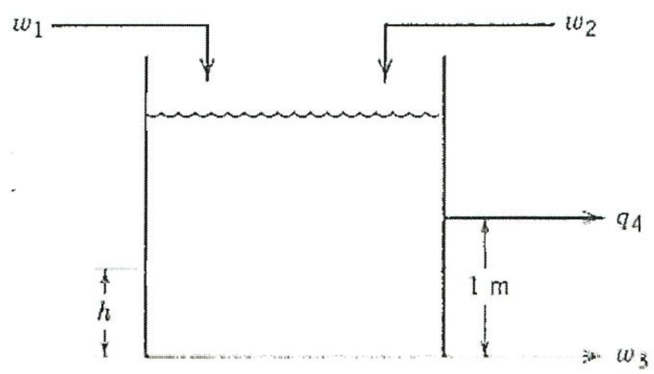

Figure Q1 (b): Leaking Surge Tank

(i) If the tank is initially empty, calculate the time it takes for the liquid level to reach the corrosion point.

(4 marks)

(ii) If mass flow rates w_1, w_2, and w_3 are kept constant indefinitely, determine if the tank will eventually overflow. Justify your reason.

(4 marks)

(c) (i) Define control configuration known as 'SISO' and 'MIMO'.

(3 marks)

(ii) With reference to question **Q1(c)(i),** recognize each control configuration by giving examples of both using a heated tank system.

(4 marks)

Q2 (a) Interpret and choose one of the following "short statement(s)" that is correct:

(i) A transfer function can be used to provide information about how a process will respond to a single input. For a particular input change, it provides;

(v) Only steady-state information about the resulting output change.
(w) Only dynamic information about the output change
(x) Both steady-state and dynamic information about the output change

(2 marks)

(ii) Laplace transform methods that form the basis for the development of transfer functions are only applicable, strictly speaking, when the process model is linear. If a process model is nonlinear:

(v) A transfer function cannot be obtained.
(w) A transfer function that describes the process operation exactly can be obtained
(x) A transfer function that describes the process operation approximately can be obtained.

(2 marks)

(iii) Three functions of the Laplace operator s are denoted by M(s), U(s) and Y(s). These represent:
(v) Transfer Functions
(w) Process inputs that have been transformed
(x) Process outputs that have been transformed
(y) None of (v to x)
(z) Any of (v to x)

(2 marks)

(b) A jacketed vessel is used to cool a process stream as shown in **Figure Q2 (b).** The following information is available:
(i) The volume of liquid in the tank V and the volume of coolant in the jacket V_J remain constant. Volumetric flow rate q_F is constant, but q_J varies with time.
(ii) Heat losses from the jacketed vessel are negligible.
(iii) Both the tank contents and the jacket contents are well mixed and have significant thermal capacitances.
(iv) The thermal capacitances of the tank wall and the jacket wall are negligible.
(v) The overall heat transfer coefficient for transfer between the tank liquid and the coolant varies with coolant flow rate:

Overall heat transfer coefficient, $U = Kq_J^{0.8}$

Where, U – BTU/h ft^2°F

$q_J = {ft^3}/{h}$

K = constant

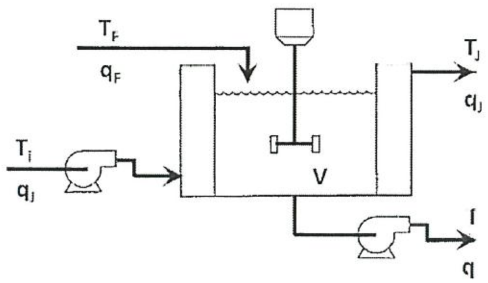

Figure Q2 (b): Jacketed vessel

Derive a dynamic model for this system (state any additional assumptions that is made).

(8 marks)

(c) For the process modelled by the following equations:

$$2\frac{dy_1}{dt} = -2y_1 - 3y_2 + 2u_1$$

$$\frac{dy_2}{dt} = 4y_1 - 6y_2 + 2u_1 + 4u_2$$

Construct the four transfer functions relating the outputs (y_1, y_2) to the inputs (u_1, u_2). The u and y are deviation variables.

(8 marks)

(d) **Figure Q2(d)** shows two flow control loops. Recognize whether each system is either a feedback or a feedforward control system. Justify your answer. It can be assume that the distance between the flow transmitter (FT) and the control valve is quite small in each system.

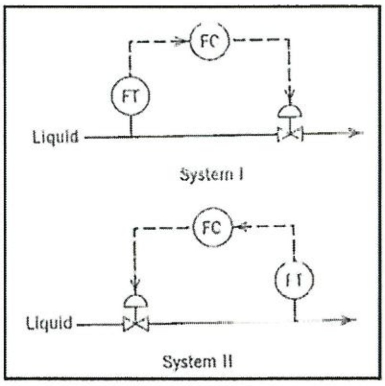

Figure Q2(d): Two flow control loops

(3 marks)

Q3 (a) Consider the following transfer function:

$$G(s) = \frac{Y(s)}{U(s)} = \frac{5}{10s + 1}$$

(i) State the steady-state gain and the time constant.

(4 marks)

(ii) If U(s) = 2/s, determine the value of the output y(t) when t → ∞

(2 marks)

(iii) If U(s) = 2/s, determine the value of the output when t = 10.

(2 marks)

(iv) If U(s) = (1 – e^{-s})/s, that is the unit rectangular pulse, determine the output when t → ∞

(2 marks)

(b) A heated process is used to heat a semiconductor wafer operates with first-order dynamics, that is, the transfer function relating changes in temperature T to changes in the heater input power level P given in **equation Q3(b).**

$$\frac{T'(s)}{P'(s)} = \frac{K}{\tau s+1} \quad \text{.......................................} \quad \textbf{equation Q3(b)}$$

Where K has units [°C/Kw] and τ has units [minutes]. The process is at steady state when an engineer changes the power input stepwise from 1 to 1.5 Kw. Determine K and τ in the process transfer function.

Given: * The process temperature initially is 80 °C.
* Four minutes after changing the power input, the temperature is 230 °C.
* Thirty minutes later the temperature is 280 °C.

(6 marks)

(c) 'Ratio control (RC) is the most elementary form of feed forward control. These control systems are almost exclusively applied to flow rate controls.'

Based on the statement above, list **THREE (3)** advantages and **THREE (3)** disadvantages of ratio control in the context of chemical engineering.

(6 marks)

(d) Relate **Figure Q3(d)** with the 1st order system characteristic

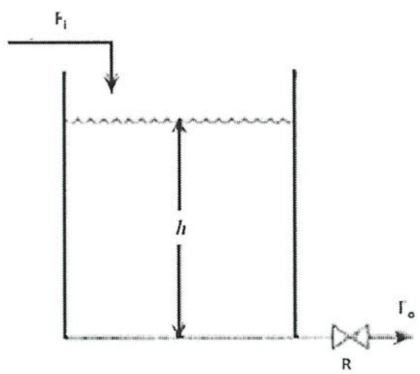

Figure Q3(d)

(3 marks)

Q4 (a) Differentiate between response time and rise time

(8 marks)

(b) Explain **THREE (3)** categories of which a second order system can occur.

(6 marks)

(c)

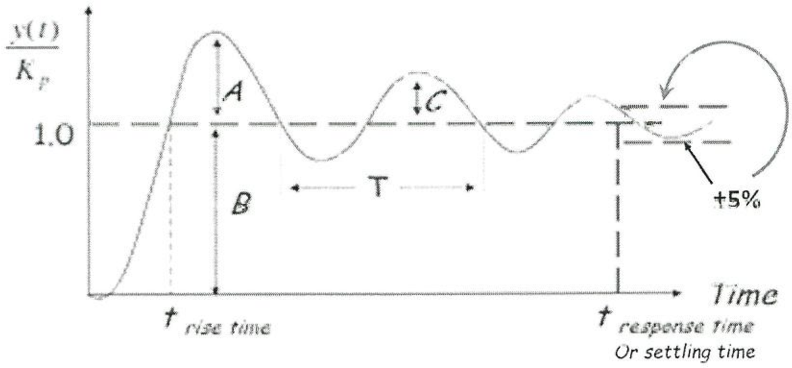

Figure Q4(c): Characteristics for the step response of an underdamped process.

With reference to **Figure Q4(c)**, interpret the meaning of the followings complete with relevant equations :

(i) Overshoot,

(ii) Decay ratio

(4 marks)

(d) (i) Compare the basic concepts of feedforward and feedback control system.

(4 marks)

(ii) Recommend the configuration of feedforward-feedback control where the feedforward controller affect the stability of the feedback control system.

(3 marks)

-END OF QUESTIONS-