NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY

FACULTY OF ENGINEERING

DEPARTMENT OF CHEMICAL ENGINEERING

INSTRUMENTATION & PROCESS DYNAMICS CONTROL

TCE 6204

Special Final Examination Paper

July 2024

This examination paper consists of 4 pages

Time Allowed: 3 hours

Total Marks: 100

INSTRUCTIONS

1. Answer **4 QUESTIONS ONLY**
2. **Question 1 (40 marks) is compulsory** and answer any other **three (3) questions (60 marks)**
3. Use of calculators is permissible
4. Graph Paper

MARK ALLOCATION

QUESTION	MARKS
1	**40**
2	**20**
3	**20**
4	**20**
5	**20**
TOTAL ATTAINABLE MARKS	**100**

Question 1

In most processing industries, surge tanks are often used as intermediate storage for fluid streams being transferred between process units. Consider the process flow diagram shown in Fig 1, where a fluid stream from **Process 1** is fed to the surge tank and the effluent from the surge tank is sent to **Process 2**.

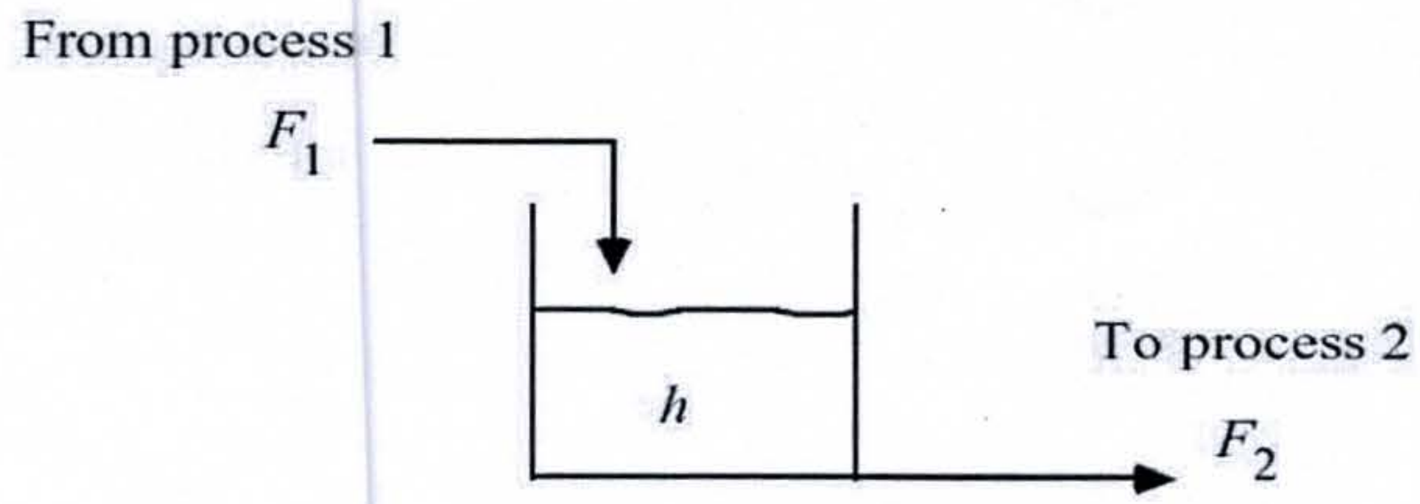

Fig. 1 Tank level problem

There are obvious constraints on the height in this tank. If the tank overflows it may create safety and environmental hazards, which may also have economic significance. Analyze this industrial process system using a step-by-step procedure.

What is/are the:

i. Control objective(s)? **[4]**

ii. Input variables and Output variables? **[3]**

iii. Constraints and Operating characteristics? **[6]**

iv. Safety, environmental and economic considerations? **[9]**

v. Control structure(s)? **[2]**

Use a Feedback (FB) control strategy to show how to achieve the control objective. Explain using a practical industrial example. **[16]**

Question 2

A. Explain the objectives of using process control systems in industrial processes. **[12]**

A thermocouple produces an e.m.f. in mV according to the temperature difference between the sensor tip θ_1 and the gauge head θ_2 in a heat exchanger such that:

$$e = \alpha(\theta_1 - \theta_2) + \beta(\theta_1^2 - \theta_2^2)$$

$\alpha = 3.5 \times 10^{-2}$ and $\beta = 8.2 \times 10^{-6}$, determine the mV output when the tip is at 220°C and the gauge head at 20°C. **[8]**

Question 3

A. Explain two important aspects of how Frequency Response Analysis is a useful 'Tool' for designing Feedback Controllers. **[6]**

B. Explain with the aid of diagrams a SISO and a MIMO system in control of Chemical Processes. **[14]**

Question 4

A stirred- tank blending process with a constant liquid holdup of 3.0 m^3 is used to blend the streams whose densities are both approximately 1 200 kg/m^3. The density does not change during mixing.

i. Assume that the process has been operating for a long period of time with flow rates of $F_1 = 800$ kg/min and $F_2 = 400$ kg/min, and feed compositions (mass fractions) of $x_1 = 0.4$ and $x_2 = 0.75$. What is the steady – state value of x? **[2]**

ii. Suppose that F_1 changes suddenly from 800 kg/min to 700 kg/min and remains at the new value. Determine an expression of response for x(t) and plot it. **[18]**

Question 5

The open loop transfer function of a control system is given as:

$$G(s) = \frac{300(s + 100)}{s(s + 10)(s + 40)}$$

i. Determine an expression for the phase angle of ***G(jw)*** in terms of the angles of its basic factors. Calculate its value at a frequency of 28.3 rad/s. **[12]**

ii. Determine the expression for the magnitude of ***G(jw)*** in terms of the magnitudes of its basic factors. Find its value in dB at a frequency of 28.3 rad/s. **[8]**

END OF EXAMINATION PAPER