Ref. No.: Ex/EE/PC/B/T/325/2024

B. E. ELECTRICAL ENGINEERING 3RD YEAR 2ND SEMESTER EXAMINATION, 2024

SUBJECT: - PROCESS INSTRUMENTATION AND CONTROL

Time: Three hours

Full Marks 100
(50 marks for each part)

Use a separate Answer-Script for each part

No. of Questions	PART I	Marks
	Answer all questions.	
1.(a)	Differentiate between lag and delay in process parameters. How can steady state gain of a process be computed? (CO1)	05
(b)	How can a sampler be implemented as an ADC equivalent and a sample-and-hold circuit be implemented as a DAC equivalent in a process control loop employing a digital controller? (CO1)	05
	OR	
	Why are current transmission standards preferred over voltage transmission standards for electrical signal transmission in a process control loop? Why is 3-15 psi standard universally adopted as the most preferred choice for pneumatic signal transmission systems? (CO1)	05
2.	With a neat diagram, explain the operating principle of a single-seat sliding-stem control valve. Here, how does plug shape play a crucial role in determining flow-lift characteristic? What are the drawbacks of a single-seat control valve and how can those be overcome? (CO3)	10
	OR	
	Explain in detail why a direct-acting actuator is known as the 'spring-to-retract' variety and a reverse-acting actuator is known as the 'spring-to-extend' variety? How can positioners help to improve linearity and response time in pneumatic actuators? (CO3)	10
3.	Write a short note on ***any one*** of the following: (CO3)	08
(i)	Pneumatic PI controllers.	
(ii)	Digital PD controllers with provision for anti-derivative kick.	

[Turn over

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No. of Questions	PART I	Marks
4.	Justify or correct ***any three*** of the following statements with suitable reasons/derivations, in brief. (CO4)	04×03 =12
(a)	In Smith's method of controlling time-delay systems, the performance of the controller greatly depends on the accuracy of estimation of the process delay but does not depend on the accuracy of estimation of the process model.	
(b)	In process controllers, under constant load conditions, bias term is provided with PI controllers to bring steady-state error to zero.	
(c)	Process controllers, equipped with AUTO/MAN modes of operation, are always designed with the 'set-point initialization' feature.	
(d)	In an equal percentage control valve, the valve sensitivity is inversely proportional to the natural logarithm of valve rangeability.	
5.	A PI controller is designed using relay autotuner method. The relay amplitude is set as 1.2 in tuning phase and the output experiences limit cycle oscillations with the input signal set as zero. Output oscillations are recorded for six complete cycles where time periods of oscillations are noted as 446 msec, 442 msec, 438 msec, 440 msec, 444 msec, and 442 msec, respectively. The maximum amplitude of the process output remained same for all six cycles. Then the controller parameters are computed using Zieglar-Nichols method. What was the maximum amplitude of the process output observed, if the proportional gain is computed as K_p = 0.38? Also determine the integral time constant of the controller designed. Derive any relation(s) used. (CO5)	10

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Part II (50 marks)

Question No. | **Question 1** is compulsory | Marks

Answer ***Any Two*** questions from the rest (2×20)

Q1 Answer ***any Two*** of the following:

(a) With the help of a schematic diagram define the following process variables associated with an automatic process control system: 5

(i) Manipulated variable, (ii) Controlled variable

(b) What is *Process Time Lag?* What are the main factors responsible for it? 5

(c) Describe "Lumped-parameter" and "Distributed Parameter" models with suitable examples. 5

(d) What is Cascade Control? When does such control scheme become useful? 5

Q2 (a) Consider the stirred-tank blending process shown in Figure Q2(a). Suppose that inlet concentration x_1 varies with time. Describe, with the help of proper schematic diagrams, the possible approaches that can be used to ensure that the outlet composition x remains at or near its desired value, x_{sp}, and discuss their relative merits and demerits. 8

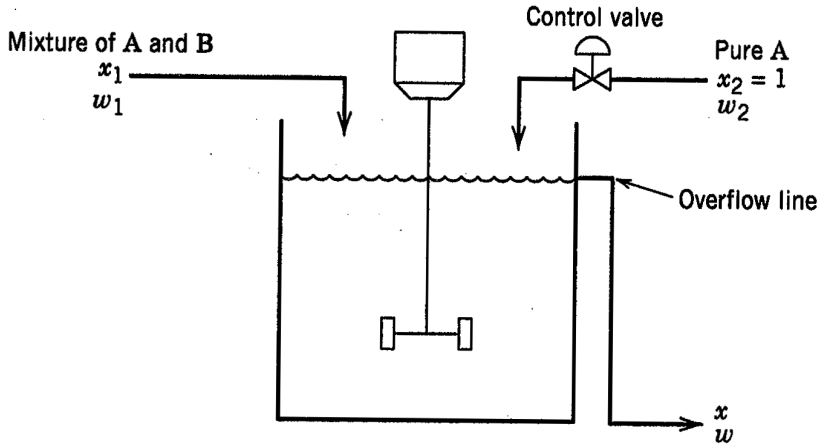

Figure Q2(a)

(b) What is feed-forward control? How is it different from feedback control? 2+2

(c) Explain, with an example, why in practical applications feed-forward control is generally used in combination with feedback control. 8

Q3 (a) Describe the methods of determining the parameters of First-Order-Plus-Time-Delay (FOPTD) model from the process reaction curve. 8

Discuss how Integrator-Plus-Time-Delay model can be used to overcome the limitations of FOPTD modeling. 4

(b) A stirred-tank blending process with a constant liquid holdup of 2 m^3 is used to blend 2 streams whose densities are both approximately 900 kg/m^3. The density does not change during mixing. Assume that the process has been operating for a long period of time with flow rates of $w_1 = 500$ kg/min and $w_2 = 200$ kg/min, and feed compositions (mass fractions) of $x_1 = 0.4$ and $x_2 = 0.75$.

(i) Obtain the steady-state value of x. 2

(ii) If w_1 changes suddenly to 400 kg/ min and remains at the new value then determine an expression for $x(t)$. 6

Q4 (a) Derive, from the basic principle, the block diagram of a PID controller realized in parallel form and explain why it is called a "Gain-Reset-Preact Controller"? 8

(b) For a type-0 system, explain how PI-controller can eliminate the steady-state offset for a step input while P-controller can only reduce it. 6

(c) What is Inferential Control? 2

With the help of a block diagram discuss the function of a Soft Sensor in an Inferential Control Scheme. 4

Q5 (a) What is Ratio Control? 2

A ratio control scheme is to be used to maintain a stoichiometric ratio of H_2 and N_2 as the feed to an ammonia synthesis reactor. Individual flow controllers will be used for both the H_2 and N_2 streams. Draw a schematic diagram for the Ratio Control scheme. 6

(b) Describe, stating the assumptions, the Ziegler Nichols method of PID controller tuning based on unit step test. 6

(c) What are *Selectors*? 2

With proper example discuss the operations of *High* and *Median Selectors*. 4