Ref. No.: Ex/EE/PC/B/T/412/2024

B. E. ELECTRICAL ENGINEERING 4TH YEAR 1ST SEMESTER EXAMINATION, 2024

SUBJECT: - PROCESS INSTRUMENTATION AND CONTROL

Full Marks 100

Time: Three hours (50 marks for each part)

Use a separate Answer-Script for each part

No. of Questions	PART I	Marks
	Answer all the questions.	
1.(a)	Why are *PID* controllers, used in process control, designed with the provision for providing a bias term? (CO1)	05
(b)	How does an ON/OFF controller operate? How does the output of an ON/OFF controller vary having two/three states and possessing/not possessing the characteristic of hysteresis? (CO1)	05
	OR	
	How is the steady-state gain computed for a process? How is the loop gain computed in a process control system? (CO1)	05
2.	In a pneumatic controller, how can one design to provide set-point in mechanical form and sense the process output as a pneumatic measured variable? Draw a neat schematic diagram of a pneumatic *PID* controller and explain how the problem of interaction between integral and derivative operations can be made small here. (CO3)	10
	OR	
	Draw a neat schematic diagram of a spring-diaphragm type actuator with positioner and explain its operating principle in detail. Hence justify how the inclusion of the positioner helps in achieving an improved performance. (CO3)	10
3.	Write a short note on ***any one*** of the following: (CO3)	08
(i)	Proportional control of a first order process with increasing time-delay.	
(ii)	Motorized rotary, motorized linear and solenoid type electric actuators.	
4.	Justify or correct ***any three*** of the following statements with suitable reasons/derivations, in brief. (CO4)	04×03 =12
(a)	In a parallel realization of an electronic *PID* controller, a single op-amp can be utilized to combine proportional and integral terms in the	

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	controller transfer function.	
4. (b)	In relay autotuner method of tuning *PID* controllers, the relay amplitude is initially set to 100% of the controller output range.	
(c)	Smith's controller for controlling time-delay systems is also known as Smith's predictor.	
(d)	A process controller can be designed with an automatic reset feature to keep provision for anti-derivative kick.	
5.	An analog *PID* controller is designed first whose proportional gain is 1.45, integral time constant is 0.96 sec. and derivative time constant is 1.64 sec. This design is then converted to a corresponding digital *PID* controller using trapezoidal rule for integration and backward difference algorithm. The sampling time is chosen as 0.1 sec. Determine the values of the coefficients of the digital *PID* controller designed. Derive all expressions used and draw the realization of the *PID* controller in block diagram form. How will the design of the digital *PID* controller change, if (*i*) the integral time constant is decreased by 20% from its base value and (*ii*) the derivative time constant is increased by 12% from its base value? (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 different process variables and control variables associated with an automatic process control system. — 5

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

(c) What is feed-forward control? How is it different from feedback control? — 5

(d) With the help of a block diagram discuss the function of a Soft Sensor in an Inferential Control Scheme. — 5

Q2 (a) What is *Process Time Lag?* What are the main factors responsible for it? — 2+4

(b) A continuous, stirred-tank blending system is shown in Figure Q2(b).

(i) Write down the Steady-State Material and Component-A balance equations. — 4

(ii) Obtain the expression for the nominal flow rate of w_2 required to produce the desired output concentration x_{sp}. — 4

(iii) Suppose that inlet concentration x_1 varies with time. What are the different schemes that can be employed to ensure that the outlet composition x remains at or near its desired value x_{sp}? — 6

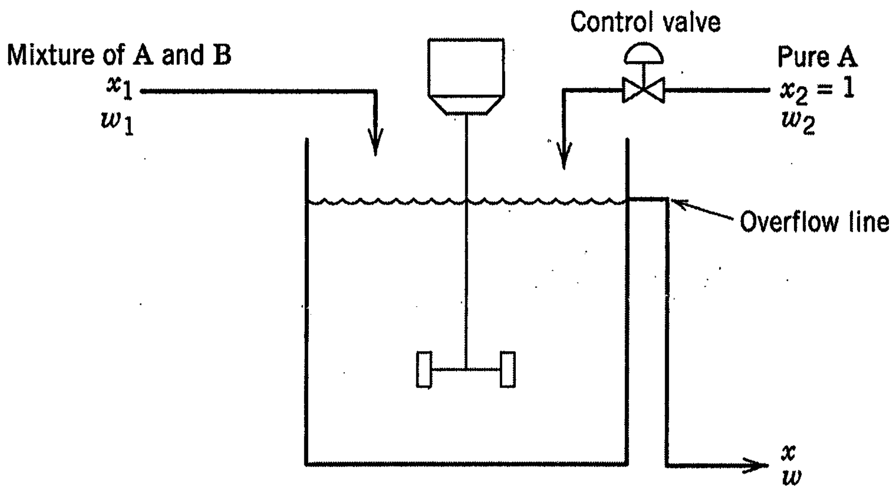

Figure Q2(b)

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Q3	(a)	What are *Fundamental* and *Empirical* Models?	2
	(b)	(i) Discuss the methods of determining the parameters of First-Order-Plus-Time-Delay (FOPTD) model from the process reaction curve.	6
		(ii) What are the limitations of FOPTD models? How they can be overcome using Integral-Plus-Time-Delay models?	2+2
	(c)	Consider a single tank liquid-level system where the outflow passes through a valve. Assume that the valve discharge rate is related to the square root of liquid level: $= C_v\sqrt{h}$, where C_v depends on the fixed opening of the valve.	
		(i) Derive an approximate dynamic model for this process by linearization.	4
		(ii) Obtain deviation variable model assuming inflow rate and the height of water in the tank to be the manipulated and controlled variable, respectively.	4
Q4	(a)	Develop the block diagram of the PID control scheme in parallel form.	4
	(b)	What is *Set Point Kick*? What are its main components?	2+2
		Show, with the help of block diagrams, how the PID control configuration needs to be modified to eliminate such phenomena.	6
	(c)	Explain, with an example, why in practical applications feed-forward control is generally used in combination with feedback control.	6
Q5	(a)	What is Ratio Control? With the help of schematic diagram discuss the different Ratio Control methods.	2+6
	(b)	Consider the stirred-tank blending process. The nominal steady-state conditions are w_1 = 600 kg/min, w_2 = 2 kg/min, x_1 = 0.05, and x_2 = 1 (for pure solute). The liquid volume and density are constant: V = 2 m^3 and ρ = 900 kg/m^3, respectively.	
		(i) Calculate the nominal exit concentration, $\bar{x}$.	4
		(ii) Derive an expression for the response, $x(t)$, to a sudden change in x_1 from 0.05 to 0.075 that occurs at time, t = 0. Assume that the process is initially at the nominal steady state.	8