SRM VALLIAMMAI ENGINEERING COLLEGE

An Autonomous Institution
SRM Nagar, Kattankulathur – 603 203

DEPARTMENT OF

ELECTRONICS AND INSTRUMENTATION ENGINEERING

QUESTION BANK

VI SEMESTER

EI3562 – PROCESS CONTROL

Regulation – 2023

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Prepared by

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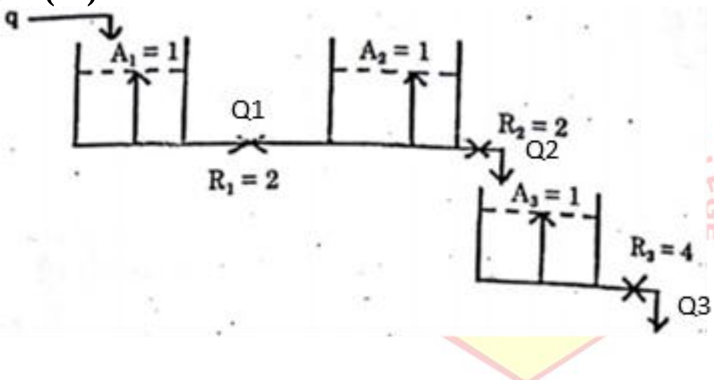
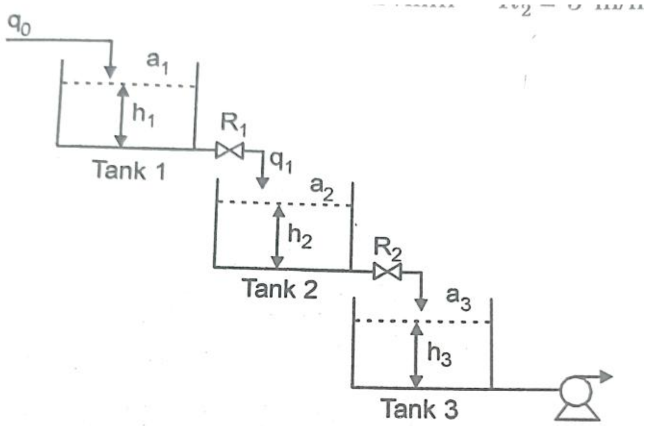
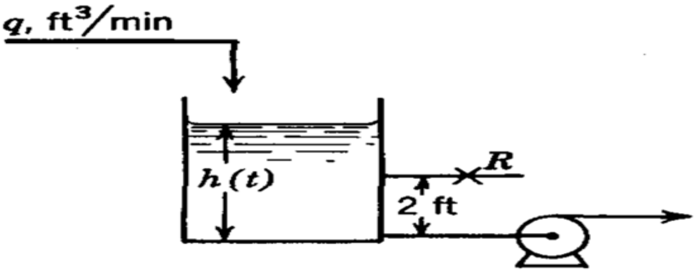
Department of Electronics and Instrumentation Engineering

SUBJECT: EI3562 PROCESS CONTROL

SEM / YEAR: VI / III

UNIT I - PROCESS MODELLING AND DYNAMICS				
SYLLABUS Need for process control – Mathematical Modeling of Processes: Level, Flow, Pressure and Thermal processes Interacting and Non Interacting systems- Degrees of Freedom – Continuous and batch processes – Self regulation – Servo and regulatory operations – Lumped and Distributed parameter models – Heat exchanger – CSTR –Linearization of nonlinear systems.				
PART –A				
Q.No	**Questions**	**COs**	**BT Level**	**Competence**
1.	What is the need for mathematical model.	CO1	BTL 1	Remember
2.	Write the mathematical model representation of pressure process.	CO1	BTL 1	Remember
3.	Compare Continuous process and Batch process.	CO1	BTL 1	Remember
4.	Obtain the mathematical model of first order Thermal process system.	CO1	BTL 2	Understand
5.	Examine the need for servo operation.	CO1	BTL 1	Remember
6.	A self-regulatory system does not require a controller. True/False. Justify the answer.	CO1	BTL 2	Understand
7.	Define controlled variable, manipulated variable and load variable in process control.	CO1	BTL 1	Remember
8.	Any process can exhibit self-regulation, Yes/No. Justify.	CO1	BTL 2	Understand
9.	What are the input and output variable for continuous and batch process?	CO1	BTL 2	Understand
10.	Compare interacting and non-interacting systems.	CO1	BTL 2	Understand
11.	A thermometer having a time constant of 1 min and is initially at 500C. it is immersed in a bath and maintained at 1000C at t = 0. Determine the temperature reading at t = 1.2 min.	CO1	BTL 2	Understand
12.	List down key objectives of process control.	CO1	BTL 2	Understand
13.	Write the list of control variables in Heat Exchanger and CSTR.	CO1	BTL 2	Understand
14.	What is non-self-regulation? Give an example.	CO1	BTL 2	Understand
15.	Define degrees of freedom.	CO1	BTL 1	Remember
16.	Differentiate servo and regulatory operations with example.	CO1	BTL 2	Understand
17.	How lumped and distributed systems are developed?	CO1	BTL 2	Understand
18.	A tank operating at 10 ft head, 5 lpm outflow through a valve and has a cross section area of 10 sq. ft. Evaluate the time constant (τ).	CO1	BTL 2	Understand
19.	Illustrate the steps involved in linearizing the nonlinear systems.	CO1	BTL 2	Understand
20.	Sketch the Heat exchanger feedback control.	CO1	BTL 2	Understand
21.	What are the four types of nonlinear functions?	CO1	BTL 2	Understand
22.	Illustrate the different methods employed in the linearization of nonlinear system.	CO1	BTL 2	Understand
23.	Define process variable.	CO1	BTL 2	Understand

24.	Compare controlled variable with manipulated variable.	CO1	BTL 2	Understand
	PART – B			
1.	Explain the need of process control in process industries. **(16)**	CO1	BTL 3	Apply
2.	Discuss the laws, languages, and levels of process control and obtain the mathematical model of a Flow process. **(16)**		BTL 4	Analyze
3.	Obtain the mathematical model of a Level process for variable and constant output rate **(16)**	CO1	BTL 4	Analyze
4.	Obtain the mathematical model of a Pressure process for variable and constant output rate **(16)**	CO1	BTL 4	Analyze
5.	**(i)** Describe a simple thermal system in which incoming liquid is heated by the heater in the tank and going out with higher temperature **(8)** **(ii)** Develop first order transfer function of the thermal process. **(8)**	CO1	BTL 4	Analyze
6.	Obtain the mathematical model of a Interacting Tank Level process **(16)**	CO1	BTL 4	Analyze
7.	Obtain the mathematical model of a Non- Interacting Tank Level process **(16)**	CO1	BTL 4	Analyze
8.	Find the transfer function $Q_3(S)/q(S)$ for the three - tank system below. **(16)** 	CO1	BTL 4	Apply
9.	Derive the transfer functions H2(s)/Q(s) and H3(s)/Q(s) for the three-tank system shown below. **(16)** 	CO1	BTL 4	Apply
10.	Explain the servo and regulatory operation with the help of suitable example. And write the Difference between them **(16)**	CO1	BTL 3	Apply
11.	Derive the transfer function H(s)/Q(s) for the liquid level system shown below when (a) The tank level operates about the steady-state value of hs =1 ft.	CO1	BTL 3	Apply

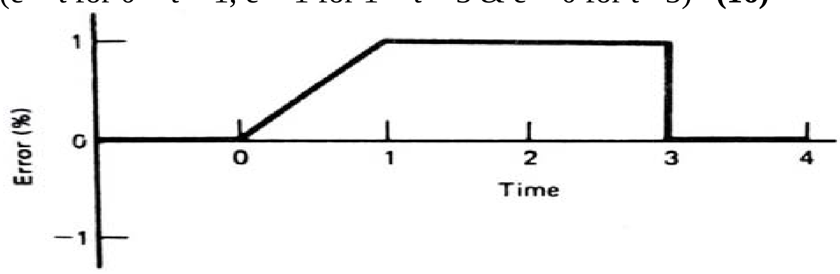
	(b) The tank level operates about the steady-state value of hs =3 ft. The pump removes water at a constant rate of 10 cfm (cubic feet per minute); this rate is independent of head. The cross-sectional area of the tank is 1.0 ft2 and the resistance R is 0.5 ft/cfm. **(16)** 			
12.	Define self-regulation. Give an example of a self-regulated process. **(16)**	CO1	BTL 3	Apply
13.	**(i)** Difference between the continuous and batch process with the help of neat diagrams. **(8)**	CO1	BTL4	Explain
14.	**(ii)** List the merits and demerits of the continuous and batch process. **(8)**			
15.	**(i)** Explain heat exchanger with a neat sketch. **(8)** **(ii)** Discuss on the functional and instrumentation diagram of Heat Exchanger. **(8)**	CO1	BTL 3	Apply
16.	**(i)** Explain the operation of CSTR with its characteristic curve and governing variables. **(8)** **(ii)** Compare lumped and distributed systems. **(8)**	CO1	BTL 3	Apply
17.	How would linearization of nonlinear system have obtained in process dynamics. Explain using level process. The flow rate through an exit pipe F0 in m3/sec is given by relation F0 = $0.6\sqrt{h}$ where h is the tank level in meter. Find time constant τ_p for the steady state levels of 2m and 5m cross sectional area of the tank A is 2m2. **(16)**	CO1	BTL 4	Analyse

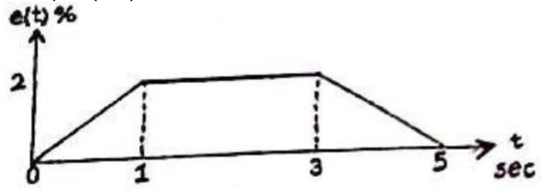
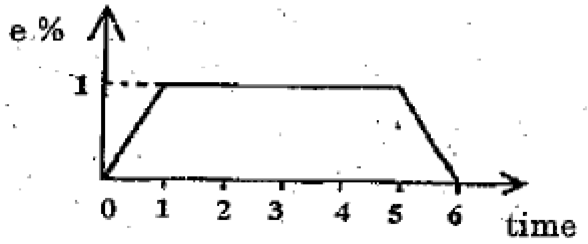
UNIT II - CONTROL ACTIONS

SYLLABUS
Characteristic of ON-OFF, Proportional, Single speed floating, Integral and Derivative controllers – P+I, P+D and P+I+D control modes – Practical forms of PID Controller – PID Implementation Issues: Bumpless, Auto/manual Mode transfer, Anti-reset windup Techniques – Direct/reverse action

PART – A

Q.No	Questions		BT Level	Competence
1.	What is the general guideline for specifying the controller action as direct/reverse?	CO2	BTL2	Understand
2.	Examine about single speed floating control.	CO2	BTL2	Understand
3.	What is meant by Neutral Zone in ON-OFF controller?	CO2	BTL2	Understand

4.	Develop the open loop response of an inverse response process when excited with unit step Input.	CO2	BTL2	Understand
5.	Justify the need for auto/ manual transfer in Industrial PID controller.	CO2	BTL2	Understand
6.	Define differential gap and its need to be presented in a process.	CO2	BTL1	Remember
7.	List the basic control actions in process control	CO2	BTL1	Remember
8.	Write down the limitations of ON/OFF controller.	CO2	BTL2	Understand
9.	Conclude why derivative mode of control is not recommended for a noisy process?	CO2	BTL1	Remember
10.	What is the importance of bias term in a controller?	CO2	BTL2	Understand
11.	What is the need for integral action in P.I controller?	CO2	BTL2	Understand
12.	What is meant by proportional band?	CO2	BTL1	Remember
13.	Define reset time.	CO2	BTL1	Remember
14.	Derivative controls cannot be used alone. Justify your answer.	CO2	BTL1	Remember
15.	Distinguish between PI controller and P controller.	CO2	BTL2	Understand
16.	Discuss integral windup and Anti reset windup.	CO2	BTL1	Remember
17.	Illustrate auto/ manual transfer in controller	CO2	BTL1	Remember
18.	Illustrate the two forms of PID algorithms.	CO2	BTL2	Understand
19.	List the various types of Anti reset windup techniques.	CO2	BTL2	Understand
20.	Compare P, l and D controller.	CO2	BTL2	Understand
21.	Compare Analog Controller with Digital Controller.	CO2	BTL2	Understand
22.	Classify the controller types based on mode of operation.	CO2	BTL2	Understand
23.	Classify the controller types based on the principle of operation.	CO2	BTL2	Understand
24.	What is meant by error and how its related to process?	CO2	BTL2	Understand
	PART – B			
1.	Examine when an on-off controller is recommended? How its performance affected by process dead time. **(16)**	CO2	BTL4	Analyse
2.	Discuss about the characteristics of on-off control and the effect of differential gap of ON-OFF controller. **(16)**	CO2	BTL3	Apply
3.	With neat schematic diagram describe the single speed multi speed floating control mode. **(16)**	CO2	BTL3	Apply
4.	Compare the features of ON & OFF, P, I, D control modes and draw their characteristics. **(16)**	CO2	BTL4	Analyse
5.	A PI controller has $K_P = 5$, $K_I = 1\ sec^{-1}$ and $P_I(0) = 20\%$. Plot the controller output for an error input as shown below. ($e = t$ for $0 < t < 1$, $e = 1$ for $1 < t < 3$ & $e = 0$ for $t > 3$) **(16)** 	CO2	BTL4	Analyse

6.	Draw the plot of PID controller output for the following error pattern. (K_P =5. τ_I = 1 sec and τ_D= 0.5 sec and $P_S(0)$ = 10%). **(16)** 	CO2	BTL4	Analyse
7.	Obtain and comment on the response of P, PI, PID controller for a step change in input. **(16)**	CO2	BTL3	Apply
8.	Compare the practical forms of Proportional, Integral and Derivative controllers available commercially. **(16)**	CO2	BTL4	Analyse
9.	Discuss the working of electronic PI and PD controller with neat diagram. **(16)**			
10.	Sketch the PID controller output for the given error signal shown in the following figure. Given that KP = 5, KI = 0.7s-1, KD = 0.5 sec and PI(0) = 20%. **(16)** 	CO2	BTL4	Analyse
11.	A PI controller has proportional band of 20% and integral time of 10seconds. For a constant error of 5%. Evaluate the controller output after 10 seconds. The controller offset is 25%. **(16)**	CO2	BTL4	Analyse
12.	Discuss the working of electronic PID controller with neat diagram. **(16)**	CO2	BTL2	Understand
13.	Design an analog **proportional-integral (PI)** controller using op-amps for a process with desired proportional gain Kp=3 and integral time Ti=5 seconds. Show the circuit diagram, select suitable component values, and derive the transfer function**. (16)**	CO2	BTL4	Analyse
14.	Given a circuit of an analog **PID controller** with three op-amps, identify the P, I, and D stages. Derive the overall transfer function from the component values R1=10kΩ, R2=100kΩ, C1=1μF, **(16)**	CO2	BTL4	Analyse
15.	Given a PD controller op-amp circuit with R=10 kΩR and C = 1μF. derive the output voltage expression when a step error input is applied. Explain how the derivative term influences the response. **(16)**	CO2	BTL4	Analyse
16.	For a given analog PI controller circuit, R=10 kΩ,C=10 μF. derive the time-domain expression for the controller output given a step input error. Comment on how integral action eliminates steady-state error. **(16)**	CO2	BTL4	Analyse
17.	Explain the implementation issues of PID Controller **(16)**	CO2	BTL3	Apply

UNIT III - PID CONTROLLER TUNING	

SYLLABUS

Evaluation Criteria IAE, ISE, ITAE and ¼ decay ratio - Tuning: Process Reaction curve Continuous cycling method and Damped oscillation method, Determination of optimum settings for mathematically described process using time response and frequency response approaches optimization methods, Auto tuning

PART-A

Q.No	Questions	COs	BT Level	Competence
1.	Define Integral Absolute Error (IAE).	CO3	BLT1	Remember
2.	What is Integral Square Error (ISE)?	CO3	BLT1	Remember
3.	Mention the significance of Integral Time Absolute Error (ITAE).	CO3	BLT2	Understand
4.	What does ¼ decay ratio signify in control systems?	CO3	BLT2	Understand
5.	Differentiate between IAE and ISE.	CO3	BLT2	Understand
6.	What is the objective of controller tuning?	CO3	BLT2	Understand
7.	List any two tuning methods used for PID controllers.	CO3	BLT1	Remember
8.	What is a Process Reaction Curve (PRC)?	CO3	BLT1	Remember
9.	State the assumptions in PRC-based tuning.	CO3	BLT2	Understand
10.	Define ultimate gain and ultimate period.	CO3	BLT1	Remember
11.	What is the purpose of the Continuous Cycling Method?	CO3	BLT2	Understand
12.	Mention one limitation of the continuous cycling method.	CO3	BLT2	Understand
13.	What is the Ziegler-Nichols continuous cycling method?	CO3	BLT2	Understand
14.	Define damped oscillation in the context of tuning.	CO3	BLT1	Remember
15.	How is the damping ratio related to control performance?	CO3	BLT2	Understand
16.	What is auto-tuning in process control?	CO3	BLT1	Remember
17.	Mention two advantages of auto-tuning.	CO3	BLT2	Understand
18.	State any one application of frequency response in controller tuning.	CO3	BLT2	Understand
19.	What is the Nyquist plot used in control system analysis?	CO3	BLT1	Remember
20.	Define time response method of tuning.	CO3	BLT1	Remember
21.	Write the expression for IAE for a unit step error signal.	CO3	BLT1	Remember
22.	What is meant by optimal controller settings?	CO3	BLT2	Understand
23.	Name any two optimization techniques used in controller tuning.	CO3	BLT1	Remember
24.	What is the role of simulation in controller performance evaluation?	CO3	BLT2	Understand

PART – B

Q.No	Questions	COs	BT Level	Competence
1.	Explain the performance criteria: IAE, ISE, and ITAE with suitable examples. **(16)**	CO3	BLT3	Apply
2.	Analyze and compare IAE, ISE, ITAE, and ¼ decay ratio for evaluating controller performance. **(16)**	CO3	BLT4	Analyze
3.	Describe the working of the Process Reaction Curve (PRC) method for controller tuning. **(16)**		BLT3	Apply
4.	Analyze the limitations of the PRC method in tuning PID controllers. **(16)**	CO3	BLT4	Analyze
5.	Explain the Continuous Cycling Method and its application in determining ultimate gain and period. **(16)**	CO3	BLT3	Apply

6.	Compare the continuous cycling method and damped oscillation method. **(16)**	CO3	BLT4 BLT3	Analyze Apply
7.	Describe the Damped Oscillation Method used in PID controller tuning. **(16)**			
8.	Analyze the suitability of various tuning methods for first-order plus dead-time (FOPDT) systems. **(16)**	CO3	BLT4	Analyze
9.	Explain how frequency response analysis helps in controller tuning. **(16)**	CO3	BLT3	Apply
10.	Compare the controller settings obtained using time response and frequency response approaches. **(16)**	CO3	BLT4	Analyze
11.	Describe optimization techniques used in tuning PID controllers. **(16)**	CO3	BLT3	Apply
12.	Analyze how tuning parameters affect the stability and performance of a control loop. **(16)**	CO3	BLT4	Analyze
13.	Explain the principle of auto-tuning and its implementation in modern controllers. **(16)**	CO3	BLT3	Apply
14.	Compare manual tuning and auto-tuning in terms of accuracy and adaptability. **(16)**	CO3	BLT4	Analyze
15.	Discuss the tuning process for a mathematically modeled second-order system using time response. **(16)**	CO3	BLT3	Apply
16.	Analyze the controller tuning strategy for a nonlinear process using optimization methods. **(16)**	CO3	BLT4	Analyze
17.	Explain how ITAE criterion is applied to optimize controller parameters using simulation results. **(16)**	CO3	BLT3	Apply

UNIT IV - FINAL CONTROL ELEMENTS

SYLLABUS

Actuators: Pneumatic and electric actuators – Control Valve Terminology - Characteristic of Control Valves: Inherent and Installed characteristics - Valve Positioner – Modeling of a Pneumatically Actuated Control Valve – Control Valve Sizing: ISA S 75.01 standard flow equations for sizing Control Valves – Cavitation and flashing – Control Valve selection

PART – A

Q.No.	**Questions**	**COs**	**BT Level**	**Competence**
1.	Point out the function of Pneumatic control valve in a flow control system.	CO4	BTL2	Understand
2.	Give the functions of an actuator and list different types of actuators.	CO4	BTL2	Understand
3.	Mention the use of electrical actuators.	CO4	BTL1	Remember
4.	Compare pneumatic and electric actuators.	CO4	BTL2	Understand
5.	Mention the functions of valve positioner.	CO4	BTL1	Remember
6.	State the need of valve positioner.	CO4	BTL2	Understand
7.	Discuss “quick opening” control valve.	CO4	BTL2	Understand
8.	Why an equal percentage valve is called as “equal percentage” valve?	CO4	BTL2	Understand
9.	Analyze why equal percentage valve is mostly used in process	CO4	BTL2	Understand

	industries?			
10.	Why installed characteristics of a control valve is different from inherent characteristics?	CO4	BTL2	Understand
11.	Draw the inherent valve characteristics of an equal percentage valve.	CO4	BTL1	Remember
12.	Define Control Valve sizing.	CO4	BTL2	Understand
13.	Summarize the factors to be considered in control valve sizing.	CO4	BTL1	Remember
14.	What is range ability of a control valves?	CO4	BTL1	Remember
15.	A valve with a C_V rating of 4.0 is used to throttle the flow of glycerin for which G = 1.26. Develop the maximum flow rate through the valve for a pressure drop of 100 psi.	CO4	BTL1	Remember
16.	Design the size coefficient of a fully open 3 inch valve has flow rate of water is 150gpm, at a differential pressure of 6 PSI.	CO4	BTL2	Understand
17.	What is ISA S 75.01 standard?	CO4	BTL2	Understand
18.	Which is not covered in ISA S 75.01 standard?	CO4	BTL2	Understand
19.	Differentiate flashing and cavitation in a control valve.	CO4	BTL2	Understand
20.	Classify the different types of process parameters to be considered in selection of control valves.	CO4	BTL2	Understand
21.	List the parts present in basic block diagram of a process control loop.	CO4	BTL2	Understand
22.	What are the two types of converters that are important for Final Control Elements present in process control?	CO4	BTL2	Understand
23.	Summarize the types of seat plug in final control element.	CO4	BTL2	Understand
24.	Classify the control valve based on the flow characteristics and rotor shaft.	CO4	BTL2	Understand
	PART – B			
1.	Explain the construction and working of pneumatic actuators. **(16)**	CO4	BTL3	Apply
2.	Explain the construction and working of Electric actuators. **(16)**	CO4	BTL3	Apply
3.	Compare pneumatic and electric actuators in terms of performance metrics. **(16)**	CO4	BTL4	Analyze
4.	Define ‘Control Valve’. Differentiate between inherent and installed characteristics of valves. **(16)**	CO4	BTL4	Analyze
5.	Discuss the role of a valve positioner and its impact on control response. **(16)**	CO4	BTL3	Apply
6.	Model a pneumatically actuated control valve and derive its transfer function. **(16)**	CO4	BTL4	Analyze
7.	Explain ISA S75.01 equation for liquid valve sizing with derivation. **(16)**	CO4	BTL4	Analyze
8.	Calculate Cv for liquid flow using ISA standard. State assumptions. **(16)**	CO4	BTL4	Apply
9.	Explain cavitation in control valves and suggest preventive methods. **(16)**	CO4	BTL3	Apply
10.	Define flashing and distinguish it from cavitation. Suggest control strategies. **(16)**	CO4	BTL4	Analyse
11.	Explain procedure and factors in control valve selection. **(16)**	CO4	BTL3	Apply
12.	Explain working of diaphragm pneumatic actuators and response to signals. **(16)**	CO4	BTL4	Analyse
13.	Write notes on: (i) Deadband (ii) Rangeability (iii) Hysteresis. **(16)**	CO4	BTL3	Apply

14.	Illustrate performance improvement using valve positioner in a feedback loop. **(16)**	CO4	BTL4	Analyze
15.	Explain steps in valve sizing with a compressible flow example. **(16)**	CO4	BTL4	Analyze
16.	Describe dynamic response factors of a control valve. **(16)**	CO4	BTL3	Apply
17.	Evaluate pros and cons of smart electric actuators in automation. **(16)**	CO4	BTL3	Apply

UNIT V - CONTROL SCHEMES

SYLLABUS

Feed forward and Feedback Control Ratio Control, Cascade Control _ Inferential Control -Split Range Control Introduction to multiloop control schemes-Smith Predictor Control Scheme - Internal Model Controller (IMC)- Adaptive controller – Introduction to Multi-loop Control Schemes – Control Schemes for Distillation column, CSTR, and Heat Exchanger - P&ID diagram.

PART – A

Q.No	Questions	COs	BT Level	Competence
1.	What is Feedback and Feed forward control?	CO5	BTL1	Remember
2.	What is Cascade Control?	CO5	BTL1	Remember
3.	How secondary controller selection is made in cascade control scheme?	CO5	BTL2	Understand
4.	List the advantages of cascade control over conventional control.	CO5	BTL2	Understand
5.	Give the advantages and disadvantages of cascade controller.	CO5	BTL2	Understand
6.	Differentiate feedback and feed forward controllers.	CO5	BTL2	Understand
7.	List the advantages and disadvantages of feed forward control.	CO5	BTL2	Understand
8.	What is dead time compensation?	CO5	BTL1	Remember
9.	Summarize the final Smith Predictor Control system diagram.	CO5	BTL2	Understand
10.	Why Smith Predictor Control scheme is recommended for dead time process?	CO5	BTL2	Understand
11.	What is IMC? Draw the block diagram	CO5	BTL2	Understand
12.	Write the need for the multi loop control.	CO5	BTL2	Understand
13.	Analyse the control objective of implementing feedback controllers in heat exchanger.	CO5	BTL2	Understand
14.	Draw any of the control scheme block diagram of CSTR.	CO5	BTL2	Understand
15.	Draw the general block diagram of Cascade Control system.	CO5	BTL2	Understand
16.	Differentiate feed forward control system with feedback control system.	CO5	BTL2	Understand
17.	Neatly sketch the feed forward control system for a heat exchanger.	CO5	BTL2	Understand
18.	Draw the block diagram of fuel air ratio control system for boilers.	CO5	BTL2	Understand
19.	How the control of chemical reactors be achieved?	CO5	BTL2	Understand

20.	What is the purpose of cascade control for heat exchangers?	CO5	BTL1	Remember
21.	Summarize the importance of model predictive controller.	CO5	BTL2	Understand
22.	What is the need for adaptive control?	CO5	BTL1	Remember
23.	Sketch any four P and ID symbols of valves.	CO5	BTL2	Understand
24.	Give the importance of P&ID diagram.	CO5	BTL2	Understand
	PART B			
1	Explain the principle and working of feedforward and feedback control systems with suitable diagrams. **(16)**	CO5	BLT3	Apply
2	Compare feedforward and feedback control in terms of disturbance handling and system stability. **(16)**	CO5	BLT4	Analyze
3	With a block diagram, explain the working of a ratio control system. **(16)**	CO5	BLT3	Apply
4	Describe the cascade control strategy and its advantages in process control. **(16)**	CO5	BLT3	Apply
5	Compare cascade control and feedforward control in terms of performance. **(16)**	CO5	BLT4	Analyze
6	Explain the concept of inferential control with a suitable industrial example. **(16)**	CO5	BLT3	Apply
7	Describe the working of a split-range control system with a control valve example. **(16)**	CO5	BLT3	Apply
8	Analyze the advantages and limitations of split-range control.	CO5	BLT4	Analyze
9	Explain the need for multiloop control schemes and give an example. **(16)**	CO5	BLT3	Apply
10	With a neat block diagram, explain the Smith Predictor Control Scheme. **(16)**	CO5	BLT3	Apply
11	Analyze the suitability of Smith Predictor for time-delay systems. **(16)**	CO5	BLT4	Analyze
12	Explain the structure and working of an Internal Model Controller (IMC). **(16)**	CO5	BLT3	Apply
13	Compare Internal Model Control and PID control in terms of response and robustness. **(16)**	CO5	BLT4	Analyze
14	Explain the working of an adaptive controller with an example. **(16)**	CO5	BLT3	Apply
15	Discuss the advantages and limitations of adaptive control in nonlinear systems. **(16)**	CO5	BLT4	Analyze
16	Draw and explain the control scheme for a distillation column. **(16)**	CO5	BLT3	Apply
17	Analyze control challenges and strategies used in a Continuous Stirred Tank Reactor (CSTR). **(16)**	CO5	BLT4	Analyze