PROCESS CONTROL SYSTEM DESIGN
(AEIE 5202)

Time Allotted : 2½ hrs **Full Marks : 60**

Figures out of the right margin indicate full marks.

Candidates are required to answer Group A and any 4 (four) from Group B to E, taking one from each group.

Candidates are required to give answer in their own words as far as practicable.

Group – A

1. Answer any twelve: **12 × 1 = 12**

Choose the correct alternative for the following

(i) The transfer function of a first order process with delay time of 0.1 sec. is represented by

(a) $\frac{K}{0.1s+1}$ (b) $\frac{K}{\tau s+0.1}$ (c) $\frac{K\,e^{-0.1s}}{\tau s+1}$ (d) $\frac{K\,e^{0.1s}}{0.1s+1}$

(ii) The truth values of traditional set theory is _____ and that of fuzzy set is _____

(a) Either 0 or 1, between 0 & 1
(b) Between 0 & 1, either 0 or 1
(c) Between 0 & 1, between 0 & 1
(d) Either 0 or 1, either 0 or 1.

(iii) Many digital control systems utilize Ethernet as a communications network, because

(a) No terminating resistors are necessary
(b) Speed is not affected by traffic
(c) It is a wireless network standard
(d) It is robust and inexpensive

(iv) Two interacting level tanks when connected in series, the overall system response become a _____ system

(a) Zero order
(b) 1st order
(c) 2nd order
(d) Integral system

(v) The TF of a Distillation column is $\frac{1.5e^{-\theta S}}{(25.5s+1)^{10}}$; the time constant and number; the time constant and number of trays respectively

(a) 25.5, 1.5 (b) 10, 0 (c) 25.5, 10 (d) 10, 1.5

(vi) If $\tilde{A}=\{(x_1,0.2),(x_2,0.3),(x_3,0.5)\};\mu_{A^3}(x_1)$ equals to

(a) 0.0025 (b) 0.009 (c) 0.008 (d) 0.0008

(vii) For modelling of a stirred tank heater system principle of _____ conservation need to be considered.

(a) total mass
(b) momentum
(c) total energy
(d) both (a) and (c)

(viii) The three "elements" in a three-element boiler drum level control system are

(a) Feedwater flow, water conductivity, and steam flow
(b) Drum level, water pH, and drum temperature
(c) Turbidity, feedwater flow, and temperature
(d) Steam flow, drum level, and feedwater flow.

(ix) The z-transform of $\frac{1}{s+a}$ is

(a) $\frac{z}{z-ae^{-aT}}$ (b) $\frac{z}{z-e^{-aT}}$ (c) $\frac{e^{aT}}{z-a}$ (d) $\frac{az^{-aT}}{z-T}$

(x) What type of control system uses feedback to adjust the output in order to maintain a constant set point?

(a) Open-loop control
(b) Closed-loop control
(c) Hybrid control
(d) None of the above.

Fill in the blanks with the correct word

(xi) Unit of the potential in level control is _____.

(xii) The Laplace transform of unit step signal is _____.

(xiii) The standard pneumatic transmitter signal in process industry is _____.

(xiv) The electrical analogy of capacitance in level measurement is _____.

(xv) The number of poles in a PI controller is _____.

Group - B

2. (a) Derive the transfer function of the given equation $2\frac{d^2y}{dt^2}+5\frac{dy}{dt}+3y=2u$. *[(CO1)(Analyze/IOCQ)]*

(b) A vessel of capacity C is being pressurized at pressure P_2 by a compressor of pressure P_1, through a valve of resistance R. (i) Derive the transfer function of the process and the time lag of the process (ii) Evaluate the transient response of the model for ramp input and (iii) Calculate Steady state value of the response and value at time lag. *[(CO1)(Analyse/IOCQ)]*

(b) Distinguish between interacting and non-interacting type level system. *[(CO1)(Understand/LOCQ)]*

2 + (3 + 3 + 2) + 2 = 12

3. (a) Illustrate controllability of a process from its process reaction rate curve. *[(CO1)(Understand/LOCQ)]*

(b) Implement proper automatic control scheme to control an overhead water tank of height 2 mt. Explain your control strategy step by step with proper control diagram for a set point of 1.5 mt tank height. Calculate the corresponding transmission signal of transmitter for height of 1.25 mt. *[(CO1)(Apply/IOCQ)]*

(c) A blending tank mixes two liquids hot and cold. Input mass flow rates are w_h and w_c, and corresponding temperatures are T_h and T_c respectively of hot and cold liquid. A is the area of cross section of the tank. ρ is the mixer density and T_{ref} is the mixture temperature. Derive the overall model of the system for outlet mass flow rate of w with temperature T. *[(CO1)(Evaluate/HOCQ)]*

2 + 5 + (2 + 3) = 12

Group - C

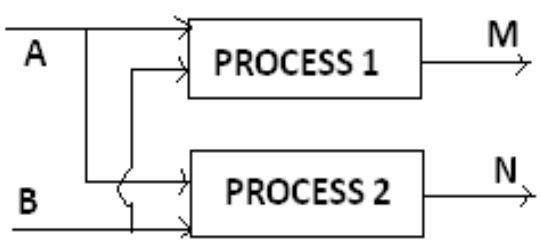
4. (a) Explain half duplex and full duplex mode of communication with one example of each. Describe the function of Master Terminal Unit (MTU) of SCADA system. *[(CO3)(Understand/LOCQ)]*

(b) With a neat and labelled diagram, explain the SCADA architecture. What are the main differences between distributed control systems and SCADA? *[(CO3)(Understand/LOCQ)]*

(2 + 2 + 2) + (4 + 2) = 12

5. (a) Describe different phases of model development? *[(CO2)(Remember/LOCQ)]*

(b) A section of a chemical plant makes two speciality products (M, N) from two raw materials (A, B) that are in limited supply. Each product is formed in a separate process as shown in fig. Raw materials A and B do not have to be totally consumed. Process reactions are: Process 1: A+B=M
Process 2: A+2B=N



The processing cost includes the cost of utilities and supplies. Labour and other costs are Rs.500/day for process1 and Rs.600/day for process2. These costs occur even there is no production. Formulate the objective function as the as the total operating profit per day. List the equality and inequality constraints.

Available Information

Raw	Maximum available (Kg/day)	Cost Rs./Kg)
A	20,000	2
B	15,000	4

Process	Product	Reactant requirements (kg) per kg product	Processing cost	Selling price of product	Max. production level (kg/day)
1	M	2/3 A, 1/3 B	2 Rs./kg M	8 Rs./kg M	15,000
2	N	½ A, ½ B	1 Rs./kg N	6 Rs./kg N	15,000

[(CO2)(Analyze/LOCQ)]

4 + (4 + 4) = 12

Group - D

6. (a) Given two fuzzy sets U and V with same elements [1,2,3,4]. Formulate a closeness relation matrix $\mu_R(u,v)$ from the elements of the sets. *[(CO5)(Create/HOCQ)]*

(b) Explain the steps to design a model reference adaptive controller with proper mathematical steps and schematic diagram. *[(CO4)(Understand/LOCQ)]*

(c) When should you use adaptive controller in place of conventional controller? *[(CO4)(Remember/LOCQ)]*

4 + 6 + 2 = 12

7. (a) Demonstrate triangular type membership function with appropriate diagram and show the mathematical formulation. *[(CO5)(Understand/LOCQ)]*

(b) The discretized membership functions of fuzzy set A and B are represented by:

$$\mu_A(x)=\left\{\frac{0.2}{1}+\frac{0.4}{2}+\frac{0.8}{3}+\frac{0.9}{4}+\frac{1}{5}\right\}$$

$$\mu_B(x)=\left\{\frac{0.9}{1}+\frac{0.6}{2}+\frac{0.5}{3}+\frac{0.4}{4}+\frac{0.1}{5}\right\}$$

Where, x= {1,2,3,4 and 5}.
Determine the union, intersection, difference and disjunctive sum of the given two fuzzy sets. *[(CO5)(Evaluate/HOCQ)]*

4 + (1 + 1 + 3 + 3) = 12

Group - E

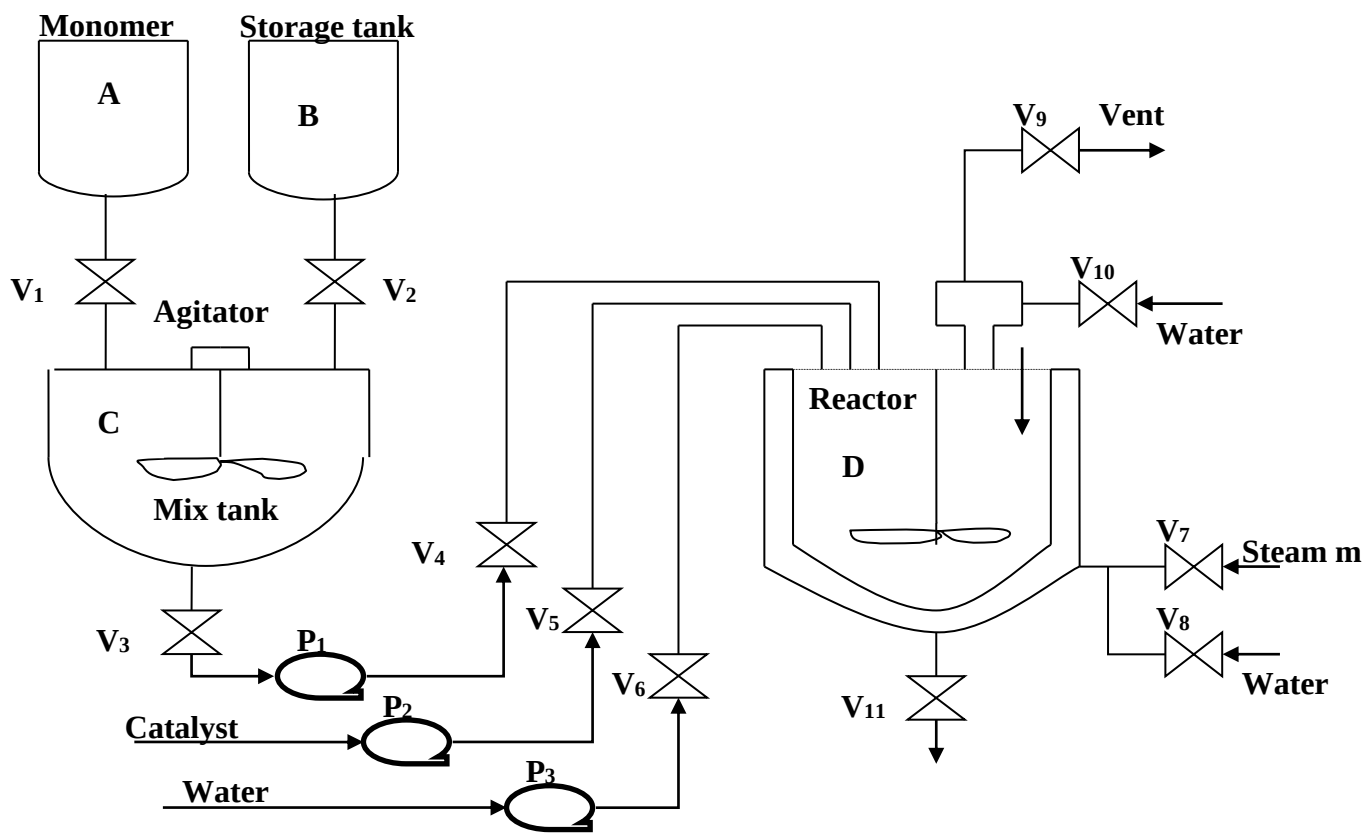
8. (a) Derive the mathematical model of distillation column. *[(CO6)(Analyse/IOCQ)]*
   (b) Explain the scheme to measure and control the thickness of a metal strip. *[(CO6)(Remember/LOCQ)]*
   (c) The following data is noted from an open test of an oven, is it possible to identify the system model from the data provided in the table? If yes, derive the model.

Initial input voltage (volt)	Final input voltage (volt)	Initial output voltage (volt)	Final output voltage(volt)	Time constant (sec.)	Dead time (sec.)
0.29	0.79	0.75	2.25	3170	280

[(CO6)(Evaluate/HOCQ)]

4 + 5 + 3 = 12

9. The component A and B is mixed in tank C. The mixture, catalyst and water in presence of some other components produce thermostat resin.
   (i) Outline the control problem and draw the proper diagram.
   (ii) Show how by using the batch controller, the control problem is efficiently tackled.



[(CO6)(Apply/IOCQ)]

(2 + 4) + 6 = 12

Cognition Level	LOCQ	IOCQ	HOCQ
Percentage distribution	38.54	40.62	20.83

Course Outcome (CO):

After the completion of the course students will be able to

1. Explain the importance of process modeling, identification and analyze process dynamics.
2. Address the importance of optimization and solve the optimization problem.
3. Understand the architecture of process control system like DCS and SCADA.
4. Apply their knowledge of adaptive control for effective process control.
5. Design process control system applying different linear, nonlinear and soft-computing techniques.
6. Explain the control mechanism of different industrial processes

**LOCQ: Lower Order Cognitive Question; IOCQ: Intermediate Order Cognitive Question; HOCQ: Higher Order Cognitive Question.*