M.TECH/AEIE/2ND SEM/AEIE 5202/2022

PROCESS CONTROL SYSTEM DESIGN
(AEIE 5202)

Time Allotted : 3 hrs **Full Marks : 70**

Figures out of the right margin indicate full marks.

Candidates are required to answer Group A and any 5 (five) from Group B to E, taking at least one from each group.

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

Group – A
(Multiple Choice Type Questions)

1. Choose the correct alternative for the following: **10 × 1 = 10**

(i) Series RLC circuit is a _____order system.
(a) First (b) Second (c) Third (d) Fourth

(ii) How many poles are there in a PD controller?
(a) 1 (b) 2 (c) 3 (d) 0.

(iii) Dual control is a/an _____ control.
(a) adaptive (b) cascade (c) batch (d) supervisory

(iv) The Laplace transfer function of a 2 second transportation lag element is represented in s-domain by
(a) $1/(s+2)$ (b) e^{2s} (c) e^{-2s} (d) $e^{-s/2}$

(v) In electrical-pneumatic system analogy the current is considered analogous to
(a) velocity (b) pressure (c) density (d) air flow rate.

(vi) In summer, weather is hot. The hotness can be represented in fuzzy logic by
(a) Λ MF (b) Γ MF (c) Gaussian MF (d) Π MF

(vii) Parity bits are used for the purpose of — in digital systems.
(a) power monitoring (b) symmetry generation
(c) diagnostic monitoring (d) error detection

(viii) Fuzzy controller can be used to control _____
(a) linear system (b) nonlinear system
(c) complex system (d) all of these.

(ix) STR is a/an _____ control.
(a) adaptive (b) cascade (c) batch (d) PID

(x) Fuzzy logic is a _____ valued logic.
(a) binary (b) multi (c) single (d) binary or multi

Group- B

2. (a) Give example of a linear and a nonlinear process model. [(CO1)(Remember/LOCQ)]

(b) Application of step response in a process results in an output as shown in Fig. 1. Identify the process model from the given observations: Z=5, (t1,y1) and (t2,y2) are the two Points marked as (3, 0.5) and (7,3.5) respectively. [(CO1)(Analyze/IOCQ)]

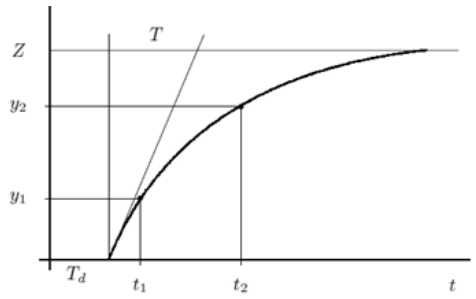

Fig. 1

(c) A liquid tank as shown in Fig. 2 has cross-sectional area of A. Two inlet flows are 10 and 5 ltr/minute and output flow is 8 ltr/minute. Taking h as the average operating level of the liquid, develop a mathematical model and calculate the level at steady state. [(CO1)(Analyze/IOCQ)]

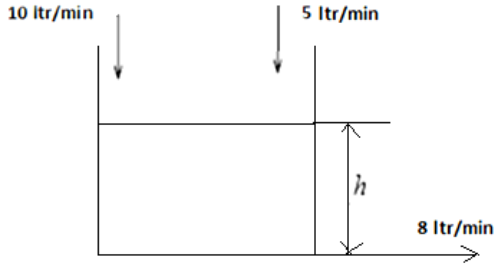

Fig. 2

2 + 5 + (3 + 2) = 12

3. (a) Determine the mathematical model of the two cart system shown in Fig. 3, where, F(t) is the force applied, m_1 and m_2 are two masses experienced the displacement x_1 and x_2 respectively. k_1 and k_2 are spring coefficients, whereas c_1, c_2 and c_3 represent damping coefficients. [(CO1)(Evaluate/HOCQ)]

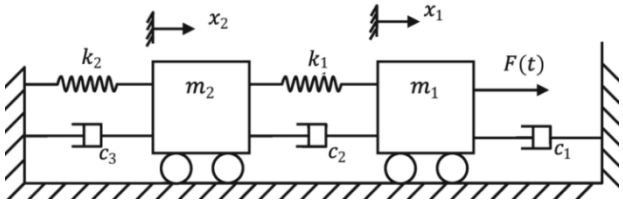

Fig. 3

(b) Solve the differential equation model for unit step input u(t) $\frac{d^2y}{dt^2}+3\frac{dy}{dt}+2y=2u(t)$ for the given initial conditions $y(0)=y'(0)=0$. [(CO1)(Analyze/IOCQ)]

(c) Derive the Z transform of the unit delay function f(k-1). [(CO1)(Analyse/IOCQ)]

6 + 3 + 3 = 12

Group - C

4. (a) Discuss how centralised optimization model differs from distributed optimization model with suitable block diagram. [(CO2)(Analyse/IOCQ)]
   (b) State the procedures to be followed for solving optimization problems? [(CO2)(Understand/LOCQ)]

6 + 6 = 12

5. (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

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 we 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 mathematical formulation. [(CO5)(Understand/LOCQ)]
   (b) The discretized membership functions of fuzzy sets 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 plate. [(CO6)(Understand/LOCQ)]
   (b) Design a scheme to measure and control the thickness of a metal strip. [(CO6)(Understand/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. [(CO6)(Analyse/IOCQ)]

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

4 + 5 + 3 = 12

9. (a) Describe the negative feedback closed loop control block diagram of an oven for temperature control. [(CO6)(Remember/LOCQ)]

(b) Calculate the mathematical model of Digital to Analog Converter (DAC) for ZOH circuit. [(CO3)(Analyze/IOCQ)]

(c) The transfer function of an oven is $G(s) = \frac{2}{100s+1}$; Then derive $G_{ZAS}(z)$ of the oven system. [(CO6)(Evaluate/HOCQ)]

5 + 3 + 4 = 12

Cognition Level	LOCQ	IOCQ	HOCQ
Percentage distribution	47.92	33.33	18.75

Course Outcome (CO):

After the completion of the course, the 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