

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) Washing machine is an example of
 - (a) Close loop control system
 - (b) Open loop control system
 - (c) Servo control system
 - (d) Regulatory control system.
- (ii) The dynamics of a second order system is given by $8 \frac{d^2y}{dt^2} + 3 \frac{dy}{dt} + 2y = 3x$. The time constant for the system is
 - (a) 8/3 Sec
 - (b) 3/8 Sec
 - (c) 4 Sec
 - (d) 2 Sec
- (iii) Which of the following is NOT a typical component of a DCS?
 - (a) Field devices
 - (b) Human Machine Interface (HMI)
 - (c) Programmable Logic Controllers (PLCs)
 - (d) Distributed controllers
- (iv) What does the term "fieldbus" refer to in a DCS?
 - (a) A type of field device
 - (b) A bus used for communication between controllers and field devices
 - (c) A monitoring tool for field devices
 - (d) A server that stores control algorithms
- (v) Which of the following best describes the structure of a Distributed Control System (DCS)?
 - (a) A single central controller connected to field devices
 - (b) A network of decentralized controllers, each controlling specific sections of the process
 - (c) A centralized database storing all control data
 - (d) A simple supervisory control layer over a PLC
- (vi) _____ represents the fuzzy logic.
 - (a) IF-THEN rules
 - (b) IF-THEN-ELSE rules
 - (c) Both (a) & (b)
 - (d) None of the above

(vii) Which of the following represents the values of fuzzy set membership?
(a) Degree of truth (b) Probabilities
(c) Discrete set (d) Both (a) & (b)

(viii) What is the primary purpose of a boiler drum level control system?
(a) To maintain the steam pressure inside the drum
(b) To control the water level inside the boiler drum
(c) To control the temperature of the steam
(d) To maintain the fuel-to-air ratio

(ix) The primary purpose of a distillation column is to:
(a) Heat the mixture to a certain temperature
(b) Separate the components of a mixture based on their boiling points
(c) Control the pressure of the system
(d) Maintain the level of the liquid in the column

(x) What is typically used to control the distillation column's overhead product composition?
(a) Reboiler temperature (b) Column pressure
(c) Condenser temperature (d) Feed rate

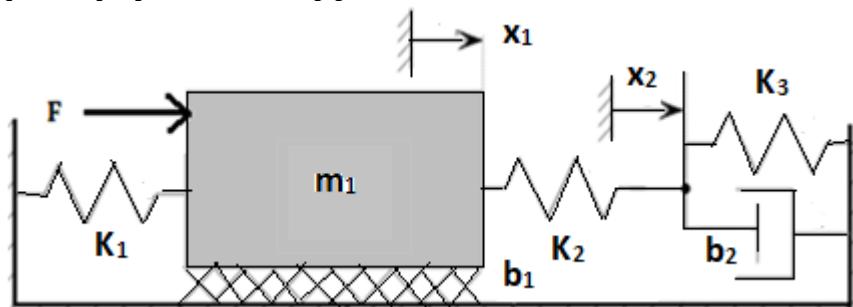
Fill in the blanks with the correct word

- (xi) The unit of capacity for the thermal system is _____.
- (xii) Series RC circuit is a _____ order system.
- (xiii) The z-transform of $\frac{1}{s+a}$ is _____.
- (xiv) Fuzzy logic is a _____ valued logic
- (xv) In closed-loop control, with a positive value of feedback the overall gain of the system will _____.

Group - B

2. (a) Solve the differential equation model $\frac{d^2y}{dt^2} + 2\frac{dy}{dt} + y = 2$; for the given initial conditions: $y(0) = y'(0) = 0$. [(C01)(Analyse/IOCQ)]

(b) Determine the mathematical model of the following mass (m_1)-spring (k_1, k_2, k_3)-damper (b_1, b_2) system for application of force F .



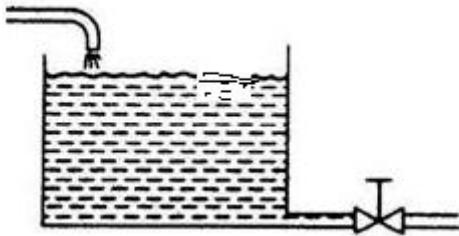
(c) Calculate the Z transform of the forward shift function $f(k+2)$.

[(C01)(Analyse/IOCQ)]

[(CO2)(Analyse/IOCQ)]

$$3 + 6 + 3 = 12$$

3. (a) Differentiate between interacting and non-interacting level systems with diagrams. [(CO1)(Understand/LOCQ)]
 (b) A liquid storage tank of cross section area F as given in the figure, having input and outflow are m and q respectively. The output valve has resistance R. Derive the mathematical model of the system for a liquid height of h.



[(CO1)(Apply/LOCQ)]

(c) If you experiment with the above model with a unit step input, find its transient and steady-state value. [(CO1)(Apply/LOCQ)]
 (d) State the relation of transfer time lag with its final steady-state value. [(CO1)(Remember/LOCQ)]

3 + 4 + (2 + 1) + 2 = 12

Group - C

4. (a) What are the main components of a Distributed Control System (DCS)? [(CO3) (Remember/LOCQ)]
 (b) How does process control model optimization work, and what are the key techniques used in this field? [(CO2) (Understand/LOCQ)]
 (c) Explain the concept of "Hot Standby" redundancy in a DCS. [(CO3) (Analyse/LOCQ)]
 (d) What is "Alarm Management" in a Distributed Control System (DCS)? [(CO3) (Analyse/LOCQ)]

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

5. (a) What is the role of communication protocols in a Distributed Control System (DCS)? [(CO3)(Analyse/LOCQ)]
 (b) Write the benefits of process model optimization. [(CO2)(Remember/LOCQ)]
 (c) What is redundancy in a Distributed Control System (DCS), and why is it important? [(CO6) (Analyse/LOCQ)]
 (d) What is the role of "Time Synchronization" in a Distributed Control System (DCS)? [(CO3) (Understand/LOCQ)]

3 + 3 + 3 + 3 = 12

Group - D

6. (a) Explain the design steps of the Gain scheduling adaptive controller. [(CO4) (Understand/LOCQ)]
 (b) Design an open loop adaptive control scheme of Hot-dip galvanizing technology for producing galvanized steel strips. [(CO4) (Understand/LOCQ)]
 (c) A fuzzy set is given as $[(x_1, 0.3), (x_2, 0.6), (x_3, 0.2)]$. Calculate the value of the power set $\mu_{B^3}(x)$. Also, determine the values of $\mu_{B^2}(x_2)$ and $\mu_{B^4}(x_3)$. [(CO5) (Analyse/LOCQ)]

3 + 5 + (2 + 1 + 1) = 12

7. Determine the following from the given fuzzy sets A, B, C, and D:

$$\mu_A(x) = \{(0.5, x_1), (0.8, x_2), (0.6, x_3), (0.3, x_4)\}$$

$$\mu_B(x) = \{(1.0, x_1), (0.8, x_2), (0.0, x_3), (0.1, x_4)\}$$

$$\mu_C(x) = \{(0.3, x_1), (0.4, x_2), (0.0, x_3), (0.8, x_4)\}$$

$$\mu_D(x) = \{(0.3, x_1), (0.7, x_2), (0.3, x_3), (0.8, x_4)\}$$

(i) $\mu_{C \cup B}(x)$ and $\mu_{A \cap C}(x)$

(ii) $\mu_{0.5*D^c}(x)$

(iii) $\mu_{A^2}(x_2), \mu_{C^3}(x_3)$

(iv) $\mu_{D-B}(x)$

(v) $\mu_{B \oplus C}(x)$

[(CO5) (Analyse/IOCQ)]

$$[(1+1)+2+(1+1)+3+3] = 12$$

Group - E

8. (a) A process is described by a delay function $f(k)$ as follows:

$$f(k) = \begin{cases} 4 \\ 0 \end{cases}$$

$f(k) = 4$ for $k=2,3,4, \dots$, and $f(k)=0$ otherwise.

Calculate the discrete model of the described process. [(CO6) (Analyse/IOCQ)]

(b) Derive the mathematical model of the distillation column plate. [(CO6) (Analyse/IOCQ)]

(c) Design a scheme to measure and control the thickness of a metal strip. [(CO6) (Analyse/LOCQ)]

4 + 3 + 5 = 12

9. (a) What is the principle of operation of a distillation column? [(CO6) (Remember/LOCQ)]

(b) What are the different types of trays used in distillation columns? Describe anyone of them. [(CO6) (Analyse/IOCQ)]

(c) How does the reflux ratio affect the separation in a distillation column and what is the role of the reboiler in a distillation column? [(CO6) (Analyse/LOCQ)]

(d) What is the importance of temperature and pressure control in a distillation column? [(CO6) (Understand/LOCQ)]

$$2 + (2+2) + (2+2) + 2 = 12$$

Cognition Level	LOCQ	IOCQ	HOCQ
Percentage distribution	48.96	51.04	0