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) The z-transform of 0.5^k is

(a) $\frac{z}{0.5+z}$ (b) $\frac{z}{z-0.5}$ (c) $\frac{0.5}{z-0.5}$ (d) $\frac{0.5}{z}$

(ii) 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) $\frac{K\,e^{0.1s}}{0.1s+1}$

(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) SCADA is

(a) real time data acquisition and processing (b) data storing
(c) data monitoring and control (d) all of the above.

(v) Series RC circuit is a _____order system.

(a) First (b) Second (c) Third (d) Fourth

(vi) If TF of a single tray in a Distillation column is $\frac{k}{(Ts+1)}$; then TF for 50 tray will be

(a) $\frac{50k}{(Ts+1)}$ (b) $\frac{k}{(Ts+1)^{50}}$ (c) $\frac{k}{(50Ts+1)}$ (d) $\frac{k}{(Ts+50)}$

(vii) The weather is very hot. Here the hot (use of linguistic variable) can be represented by _____

(a) Fuzzy Set (b) Crisp Set
(c) Fuzzy & Crisp Set (d) None of the mentioned.

(viii) In a control system output of the controller is given to
(a) Final control element (b) Amplifier
(c) Comparator (d) Sensor.

(ix) In pneumatic-electrical analogy, the electrical resistance is analogous to
(a) field helical tube (b) volume of air
(c) restriction to flow (d) none of the above.

(x) In closed loop control system, with positive value of feedback gain the overall gain of the system will
(a) decrease (b) increase
(c) be unaffected (d) any of the above.

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 $y(0)=y'(0)=0$. *[(CO1)(Analyze/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, shown in Fig.1.

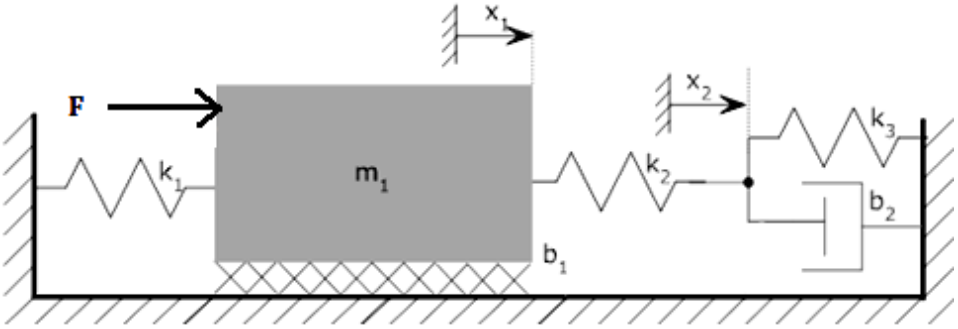

Fig.1

[(CO1)(Analyze/IOCQ)]

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

[(CO2)(Analyse/IOCQ)]

3 + 6 + 3 = 12

3. (a) Derive the mathematical model for the compressor-tyre as shown Fig.2, connected through a valve of resistance R. 'C' is the capacity of the tyre, P_1 and P_2 are the input and output pressure and Q is the air flow rate.

[(CO1)(Evaluate/HOCQ)]

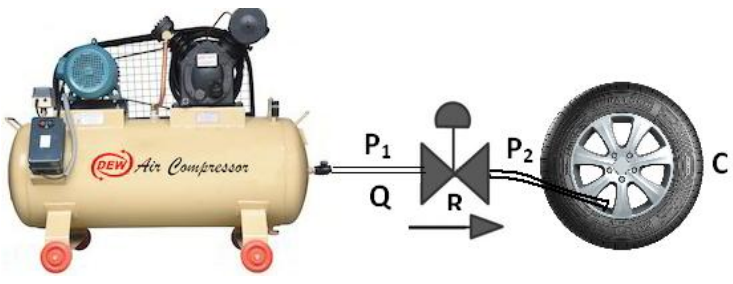

Fig.2

(b) A series of 3 heat exchangers, where a liquid of density ρ and specific heat capacity c_p is heated. T_0, T_1, T_2 and T_3 refer to the temperatures and V_1, V_2 and V_3 are respective volumes of the liquid in the heat exchangers. Derive the followings:

(i) Dynamic heat balance equation / equations for uniform volumetric flow rate q and heat inputs H as shown in Fig.3.

(ii) Steady state model.

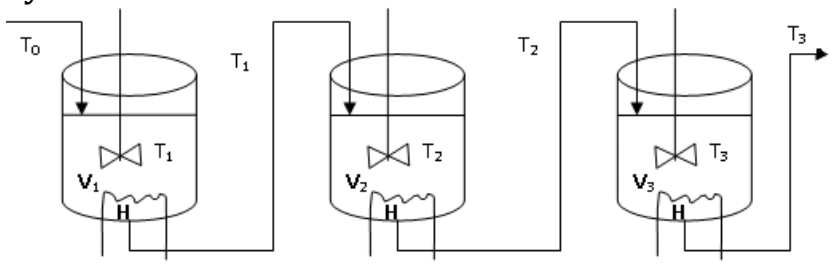

Fig.3

[(CO1)(Analyzee/IOCQ)]

4 + (5 + 3) = 12

Group - C

4. (a) Draw the direct digital control scheme used for designing of a process control system and describe the same. *[(CO3)(Understand/LOCQ)]*

(b) What do you mean by Media Access Control (MAC)? Describe the token passing mechanism use to control access to the network with suitable diagram. *[(CO3)(Understand/LOCQ)]*

(c) Analyse the demerits of monolithic SCADA systems with necessary schematic diagram. *[(CO3)(Analyse/IOCQ)]*

4 + (1 + 4) + 3 = 12

5. (a) With suitable block diagram, describe a real time optimization system commonly used in process plant. *[(CO2)(Understand/LIOCQ)]*

(b) How to estimate process model parameters using least squares method? *[(CO2)(Analyse/IOCQ)]*

6 + 6 = 12

Group - D

6. (a) Explain the design steps of 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)(Remember/LOCQ)]*

(c) A fuzzy set $\mu_B(x)$ given as $\left[(x_1,0.3),(x_2,0.6),(x_3,0.2)\right]$. Calculate the value of power set $\mu_{B^3}(x)$. Also determine the values of $\mu_{B^2}(x_2)$ and $\mu_{B^4}(x_3)$.

[(CO5)(Analyze/IOCQ)]

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

7. (a) Using Zadeh implication, build the relation matrix for the given fuzzy sets A and B:

$$A=\left\{\frac{0.2}{x_1}+\frac{0.5}{x_2}+\frac{0.9}{x_3}\right\}$$

$$B=\left\{\frac{0.1}{y_1}+\frac{0.3}{y_2}+\frac{0.7}{y_3}+\frac{0.8}{y_4}\right\}$$

[(CO) (Analyze/IOCQ)]

(b) Estimate the fuzzy set B using composition operator from the supplied data. Fuzzy set 'A' is defined by

$$A=\left\{\frac{0.3}{x_1}+\frac{0.8}{x_2}+\frac{0.1}{x_3}\right\}$$

and the corresponding relation matrix 'R' is represented by

R =

	Y_1	Y_2	Y_3	y_4
X_1	0.8	1	0.1	0.7
X_2	0	0.8	0	0
X_3	0.9	1	0.7	0.8

where μ_R is defined as $\mu_R : \tilde{A}\times\tilde{B}\in[0,1]$. *[(CO5)(Evaluate/HOCQ)]*

6 + 6 = 12

Group - E

8. (a) Derive Z transform of the function f(k)= 4u(k)+3δ(k)+$(0.4)^k$. *[(CO6)(Analyze/IOCQ)]*

(b) Demonstrate a typical distillation column dynamics with mathematical representation. *[(CO6)(Understand/LOCQ)]*

(c) Explain a scheme to improve flatness measurement and control of metal strip. *[(CO6)(Understand/LOCQ)]*

3 + 4 + 5 = 12

9. (a) Name the sensors used for boiler drum level control. *[(CO6)(Remember/LOCQ)]*

(b) What are the common problems associated with boiler drum level control and how can they be prevented by using 3 element control? Explain the control algorithm for boiler drum level control with proper diagram. *[(CO6)(Understand/LOCQ)]*

2 + (2 + 3 + 5) = 12

Cognition Level	*LOCQ*	*IOCQ*	*HOCQ*
Percentage distribution	*45.83*	*43.75*	*10.42*

Course Outcome (CO):

After the completion of the course students will be able to

1. Explain the importance of process modelling, 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.*