

**PROCESS CONTROL & INSTRUMENTATION IN CHEMICAL INDUSTRIES
(CHE3201)**

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) If volume of a CSTR is 1 m³, the volumetric flowrate 1m³/s, the rate constant 1 s⁻¹, time constant of the CSTR is
(a) 1 s (b) 0.5 s (c) 2 s (d) 3 s
- (ii) What is the Laplace transform of a unit step function?
(a) 1/s (b) 1/(s+1) (c) s/(s+1) (d) 1/(s-1)
- (iii) What is the Routh-Hurwitz criterion used for?
(a) To determine the stability of a system
(b) To design a control system
(c) To analyze the frequency response of a system
(d) To develop an empirical model
- (iv) What is the main difference between an open-loop transfer function and a closed-loop transfer function?
(a) Feedback loop (b) Stability
(c) Gain (d) Time constant
- (v) The transfer function of a second-order underdamped system is given by $G(s) = \frac{1}{(\tau^2 s^2 + 2\zeta\tau s + 1)}$; where τ is the time constant and ζ is the damping ratio. What is the condition for the system to be underdamped?
(a) $\zeta > 1$ (b) $\zeta < 1$ (c) $\zeta = 1$ (d) $\tau > 1$
- (vi) In fuzzy logic controllers, the inputs are
(a) Binary (b) Fuzzy (c) Linguistic (d) Analog
- (vii) The control systems employed in Oil and gas refineries and petrochemical industries are
(a) Distributed control systems
(b) Programmable logic control
(c) Supervisory Control and Data Acquisition
(d) Programmable automation control

- (viii) The Dynamic Matrix Control developed by Shell Oil Ltd is an example of
 (a) Internal model control (b) Model predictive control
 (c) Programmable logic control (d) Machine learning-based control
- (ix) The symbol TY in a P & ID diagram implies
 (a) Temperature transmitter (b) Temperature recorder
 (c) Temperature controller (d) Temperature converter
- (x) When a conductor of length l moves with a velocity v perpendicular to a magnetic field B , the emf e induced is given by
 (a) $e = Blv$ (b) $e = Bl/v$ (c) $e = B/lv$ (d) $e = Bv/l$

Fill in the blanks with the correct word

- (xi) The state variables in a nonisothermal CSTR are _____.
- (xii) Bode stability criterion states that _____.
- (xiii) The performance criteria ISE is expressed as _____.
- (xiv) The material of construction for thermocouple having a temperature range of 0-1500°C is _____.
- (xv) The control strategy best suited for processes spread over large geographical distances and requiring frequent intervention is known as _____.

Group - B

2. (a) Find the $x(t)$ of following linear differential equations.
 i) $\frac{dx_1}{dt} = 2x_1 + 3x_2 + 1$ with $x_1(0) = 0$
 ii) $\frac{dx_2}{dt} = 2x_1 + x_2 + e^t$ with $x_2(0) = 0$ [[CO1](Analyse/HOCQ)]
- (b) Apply final value theorem on the function $\overline{f(s)}$ to compute the value $f(t)$ as $t \rightarrow \infty$. [[CO1](Apply/IOCQ)]
10 + 2 = 12
3. (a) Define bound input, bound output and unbound output. What is the full form of MIMO and SISO? [[CO1](Analyse/HOCQ)]
- (b) A control system having transfer function $G(s) = \frac{1}{s+1} = \frac{Y(s)}{X(s)}$ is subject to input $x(t) = t$. Find the maximum difference between input and output. [[CO1](Apply/IOCQ)]
(4 + 2) + 6 = 12

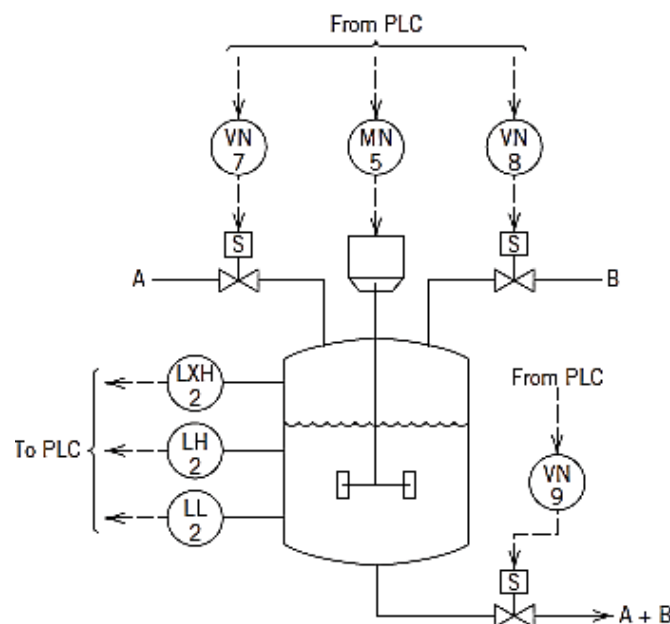
Group - C

4. (a) "Addition of P control mode makes the closed loop response faster at the expense of creating an offset". Justify the statement and obtain the expression for offset in the closed loop response of a first order system with proportional controller when a unit step change in setpoint is applied to the system. Sketch the closed loop response of the system. [[CO2](Analyse/HOCQ)]
- (b) Derive the design equation of a dynamic feedforward controller. [[CO2](Apply/IOCQ)]

- (c) Obtain the expression of closed loop response of a feedback control system to change in setpoint and load. [[CO2](Apply/IOCQ)]
4 + 4 + 4 = 12
5. (a) A PID controller is at steady state with output pressure of 9 psig. The setpoint and penpoint are initially together. At $t=0$, the setpoint is moved away from the penpoint at a rate of 0.5 mm/min. The motion of the setpoint is in the direction of lower readings. If the knob settings are $K_c=2\text{psig/mm}$ of pen travel, integral time = 1.25 min and process time constant is 0.4 min, represent graphically the variation of output pressure with time. [[CO3](Analyse/HOCQ)]
- (b) "Ratio control is a special type of feedforward control system". Justify the claim by discussing the principle of ratio control system with diagram. State one important industrial application of ratio control. [[CO3](Analyse/IOCQ)]
- (c) Explain the important performance criteria of a feedback control system. [[CO3](Understand/LOCQ)]
5 + 4 + 3 = 12

Group - D

6. (a) For the mixing process shown below, a handswitch is activated by the operator which causes the solenoid valve VN7 to be opened to introduce liquid A. When liquid level reaches LH2, flow A is stopped and B started(VN8) and a motor MN5 is started to turn on the mixer. When liquid level reaches LXH2, B is stopped and discharge valve VN9 opens. When the tank level reaches low limit LL2, the discharge valve is closed and the motor is stopped. For the above batch operation, develop
- (i) An information flow diagram (ii) A sequential function chart
 (iii) A ladder logic diagram [[CO4](Apply/HOCQ)]



- (b) Discuss with a diagram the different levels of batch control systems. [[CO3](Remember/LOCQ)]
(3 + 3 + 3) + 3 = 12

7. (a) Explain the functions of the various components of a distributed control system. [[CO4](Remember/LOCQ)]
 (b) With a neat sketch explain the distributed control architecture of a plant. [[CO4](Analyze/IOCQ)]
 (c) State the function of the different components of a PLC. [[CO4](Understand/LOCQ)]
3 + 5 + 4 = 12

Group - E

8. (a) An engineer sets the pressure in a supply tank using an accurate manometer as a guide and reads the output of a 20 psig pressure gauge attached to the tank as 10.2 psig. Sometime later, the process is repeated and the values are obtained as 10.4 psig and 10.3 psig. Comment on the gauge's (i) Precision (ii) Accuracy (iii) Resolution (iv) Repeatability
 Express the answers on a percentage full-scale basis. [[CO5](Analyse/HOCQ)]
 (b) Discuss the working principle of a hot wire anemometer with diagram. [[CO5](Remember/LOCQ)]
 (c) "An air to close valve is a fail open valve". Justify the statement. [[CO5](Apply/IOCQ)]
4 + 4 + 4 = 12
9. (a) A coolant (specific gravity 1.2) is pumped through a heat exchanger and control valve at a nominal flowrate 0.6 m³/min. The total pressure drop over this heat exchanger system is constant at 450 kPa. The pressure drop over the system without valve is proportional to the square of the flow. Its nominal value at the desired flowrate is 200 kPa. The control valve is to be designed so that the nominal flowrate is 2/3 of the maximum flowrate when the valve is completely open. Based on the information, calculate the value of valve coefficient. Given: unit conversion factor N=0.0865 m³/h(Kpa)^{1/2}. [[CO5](Analyse/HOCQ)]
 (b) Explain the working principle of an electromechanical transducer with diagram. Discuss the mechanism of action of a diaphragm gauge integrated with an electromechanical transducer during measurement of pressure. [[CO5](Remember/LOCQ)]
 (c) A transducer measures a range of 0-200 N with a resolution of 0.2% of full scale. What is the smallest change in force that can be measured by this transducer? [[CO5](Apply/IOCQ)]
4 + (3 + 3) + 2 = 12

Cognition Level	LOCQ	IOCQ	HOCQ
Percentage distribution	20.83	32.30	46.87