PROCESS CONTROL AND INSTRUMENTATION
(CHEN 3201)

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 pure capacitive system is
(a) $1/(As+1)$ (b) s/A (c) $1/As$ (d) As

(ii) In under-damped second order system, decay ratio _____ with decrease in damping factor.
(a) increases (b) decreases
(c) may increase or decrease (d) does not change

(iii) Identify an unbounded input from inputs whose transfer functions are given below
(a) (1/s) (b) 1 (c) $(1/s^2)$ (d) $1/(s^2+1)$

(iv) The time constant of a mercury thermometer is given by
(a) $\frac{hC}{mA}$ (b) $\frac{mC}{hA}$ (c) hA x mC (d) hA

(v) In case of frequency response from a second order system, the A.R. is
(a) 1 (b) more than 1
(c) less than 1 (d) may be either more or less than 1

(vi) Diaphragm gauge is used for measuring
(a) Temperature (b) Pressure (c) Liquid level (d) Flowrate

(vii) The optimum percentage of fuel and air in a combustion chamber is maintained using
(a) split range control (b) cascade control
(c) ratio control (d) single loop feedback control

(viii) The flowrate across a control valve is proportional to
(a) square of the pressure drop across the valve
(b) pressure drop across the valve
(c) square root of the pressure drop across the valve
(d) independent of the pressure drop across the valve

(ix) Temperature inside a furnace is measured using
(a) Thermocouple (b) Optical pyrometer
(c) Thermometer (d) Resistance temperature detector

(x) As per Routh Hurwitz criterion, a feedback control system will be stable
(a) If all the coefficients of the characteristic polynomial are positive
(b) If some of the elements of the first column are positive
(c) If all elements of the first column of the Routh array are positive
(d) If some of the coefficients of the characteristic polynomial are negative

Fill in the blanks with the correct word

(xi) Transfer function of a PID controller is_____.

(xii) The problem encountered in a PI controller during sustained oscillation is known as _____.

(xiii) The thermostat in a water heater is a type of_____.

(xiv) The amplitude ratio for the sinusoidal response of a _____ is 1.

(xv) In under-damped second order system, the damping factor is _____.

Group - B

2. (a) Obtain the state equations of a stirred tank heater. Mention the variables.
[(CO1)(Analyse/IOCQ)]

(b) A thermometer having a time constant of 0.1 min. was placed in a temperature bath, and after the thermometer has come to equilibrium with the bath, the temperature of the bath was increased linearly with time at a rate of 1^0C/min. Find the response as a function of time. What is the difference between indicated temperature and bath temperature after 0.2 min? *[(CO2)(Evaluate/HOCQ)]*

6 + 6 = 12

3. Two non-interacting liquid-level tanks are connected in series. The time constants are 0.8 min. and 0.5 min. respectively. The resistance of out flow from the second tank is l.0 m/m^3/min.
(i) Write down the transfer function. Is it underdamped or overdamped system?
(ii) Determine the damping factor.
(iii) Obtain the dynamic response of the liquid level in tank 2 after a unit-step change is made in the inlet flow rate to tank 1.
(iv) Also calculate the response of the liquid level in tank 2 after 2 min. of the disturbance.
(v) Determine the initial value and final value of the responses. *[(CO2)(Evaluate/HOCQ)]*

12

Group - C

4. (a) A step change of magnitude 2 units, is introduced in a damped vibratorhaving following transfer function

$$\frac{Y(s)}{X(s)} = \frac{8}{(s^2 + 2s + 9)}$$

Determine the damping factor, decay ratio, maximum value and ultimate value of the response. *[(CO2)(Evaluate/HOCQ)]*

(b) Show that a pneumatic control valve exhibits a 2nd order dynamic system. *[(CO2)(Apply/IOCQ)]*

(c) Write down the amplitude ratio and phase lag of the frequency response of a first order system. *[(CO2)(Understand/LOCQ)]*

6 + 4 + 2 = 12

5. (a) Sketch the root locus of a feedback system having the open loop transfer function given below

$$G(s) = K\frac{(s+1)(s+2)}{(s+4)(s+5)}$$

Mark the following in the diagram

(i) Open loop poles and zeros

(ii) Portion of real axis lying on root locus

(iii) Breakaway and break-in points. *[(CO3)(Apply/HOCQ)]*

(b) Compute the angle of departure of the root locus leaving a complex open loop pole $(-1+j\sqrt{2})$ if the other open loop poles for the system are 0 and $(-1-j\sqrt{2})$ *[(CO3)(Analyze/IOCQ)]*

(c) Plot the amplitude ratio and phase angle at different values of frequency of oscillation for a PI controller with K_c=2 and τ_I=10 min (mm graph required) *[(CO3)(Evaluate/HOCQ)]*

6 + 2 + 4 = 12

Group - D

6. (a) Justify the following statements

(i) Derivative control is known as anticipatory control

(ii) The time constant τ_I in a PI controller is known as reset time. *[(CO3)(Analyze/IOCQ)]*

(b) A stable process is destabilized using a PI controller. Justify the following statement for the process with the transfer function $\frac{1}{s^2 + 2s + 2}$ when a PI controller with K_c=100 and τ_I=0.1 min is added to the system.

Assume transfer functions of final control element and measuring element as 1. *[(CO3)(Analyze/IOCQ)]*

(c) Discuss an application of on-off controller. Sketch the output-input diagram for an on-off controller. *[(CO3)(Remember/LOCQ)]*

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

7. (a) For the process model given as

$$G = \frac{2e^{-s}}{(10s+1)(5s+1)}$$

(i) Plot the open loop Bode diagram and determine the crossover frequency, gain margin and phase margin (log-log and mm graph required)

(ii) Using the Ziegler Nichols controller settings, specify the gain and integral time of a PID controller

Ziegler Nichols settings for a PID controller are as follows: $K_c=0.6\ K_u$, $\tau_I=P_u/2$, $\tau_D=P_u/8$. *[(CO4)(Evaluate/HOCQ)]*

(b) Derive the expression for offset in a system comprising a first order process and PI controller when a unit step change in disturbance is applied to the system. *[(CO4)(Analyze/IOCQ)]*

(c) Explain the rationale behind Cohen Coon method of controller tuning. *[(CO4)(Understand/LOCQ)]*

(4 + 3) + 3 + 2 = 12

Group - E

8. (a) Discuss the types of dynamic characteristics of an instrument. *[(CO5)(Remember/LOCQ)]*

(b) A first order temperature measuring instrument has a rise time of 0.1 s. The instrument is initially at room temperature of 25 ° C for a long time. Then it is suddenly put to a water bath at 125 ° C. What temperature will the instrument read after 0.05 s? *[(CO5)(Evaluate/HOCQ)]*

(c) Discuss with diagram the working principle of resistance temperature detector. *[(CO5)(Understand/LOCQ)]*

(d) State the laws of thermocouple. *[(CO5)(Remember/LOCQ)]*

3 + 3 + 4 + 2 = 12

9. (a) Explain the types of control valve characteristics using a valve characteristic curve. *[(CO5)(Remember/LOCQ)]*

(b) Why equal percentage valve is named so? *[(CO5)(Understand/LOCQ)]*

(c) Represent with proper symbols the various process piping, connection and transmission lines set by ISA. *[(CO5)(Apply/IOCQ)]*

(d) Represent symbolically process input, output streams, different types of reactors and heat exchangers in standard process flow diagram. *[(CO5)(Apply/IOCQ)]*

4 + 2 + 3 + 3 = 12

Cognition Level	LOCQ	IOCQ	HOCQ
Percentage distribution	22.92	31.25	45.85

Course Outcome (CO):

After the completion of the course students will be able to

1. Formulate mathematical models explaining the static and dynamic behavior of chemical processes.
2. Solve equations arising out of dynamic behavior of systems using Laplace transformation.
3. Develop the concept of stability and apply the stability criteria suitably.
4. Apply knowledge of the control strategies for different control configuration and controller tuning.
5. Specify the required instrumentation for measurement of various process parameters in chemical process plants and understanding working principles.

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