INDUSTRIAL PROCESS CONTROL & INSTRUMENTATION
(CHEN 4111)

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

Figures out of the right margin indicate full marks.

Candidates are required to answer Group A and <u>any 5 (five)</u> from Group B to E, taking <u>at least one</u> 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 amplitude ratio for the sinusoidal response of a ________ is 1.
(a) First order system (b) Second order system
(c) Transportation lag (d) None of these

(ii) In case of step response of a ________ second order system two complex conjugate roots are obtained.
(a) critically damped (b) underdamped (c) overdamped (d) pseudo

(iii) In second order under damped system satisfy the relation
(a) decay ratio = overshoot (b) decay ratio = (overshoot)^2
(c) decay ratio = (overshoot)$^{0.5}$ (d) none of (a), (b) & (c).

(iv) The transfer function for a P-D controller is
(a) $K_C(1+\tau_D s)$ (b) $K_C(1+ 1/\tau_D s)$ (c) $K_C \tau_D s$ (d) $K_C / \tau_D s$

(v) U tube manometer exhibits
(a) first-order dynamics (b) second order dynamics
(c) multicapacity system in series (d) neither (a), (b) & (c).

(vi) Bode diagram is a plot of
(a) log (AR) vs. log (f) and (φ) vs. log (f) (b) log (AR) vs. f and log φ vs. f
(c) AR vs. log (f) and φ vs. log (f) (d) neither (a), (b) & (c).

(vii) In IMC formulation, the PID tuning parameter K_c is
(a) directly proportional to the closed loop time constant
(b) inversely proportional to the closed loop time constant
(c) independent of the closed loop time constant
(d) inversely proportional to square root of the closed loop time constant.

(viii) The FOPDT model is represented as
(a) $\dfrac{K_P e^{-\tau_d s}}{\tau s+1}$ (b) $K_P e^{-\tau_d s}$ (c) $\dfrac{K_P e^{\tau_d s}}{\tau s+1}$ (d) $K_P e^{-\tau_d s}(\tau s+1)$

(ix) A constant reflux ratio in a distillation column is maintained using
(a) Feedback control
(b) Feedforward control
(c) Cascade control
(d) Split range control.

(x) Nutating disc is an example of
(a) Variable area flowmeter
(b) Positive displacement flowmeter
(c) Constant area-variable pressure drop flowmeter
(d) Turbomagnetic flowmeter.

Group- B

2. (a) With appropriate schematic, explain feedback, feed-forward and inferential control systems for the distillate composition control of a simple distillation column.
[(CO1)(Analyze/IOCQ)]

(b) Develop the state model for a batch reactor where the following reactions are taking place:

$$A \xrightarrow{k_1} B \xrightarrow{k_3} C$$

$$A \xrightarrow{k_2} D$$

All reactions are endothermic and have first-order kinetics. The reacting mixtures are heated by steam at 10.34 bar, which flows through a jacket around the reactor with a rate of Q (kg/min.). [(CO1)(Analyze/IOCQ)]

6 + 6 = 12

3. Frame mathematical model of the mixing process as shown in Fig.1 and obtain the state equations. Identify the disturbance, manipulated variable, control objective and unmeasured outputs. [(CO1)(Analyze/IOCQ)]

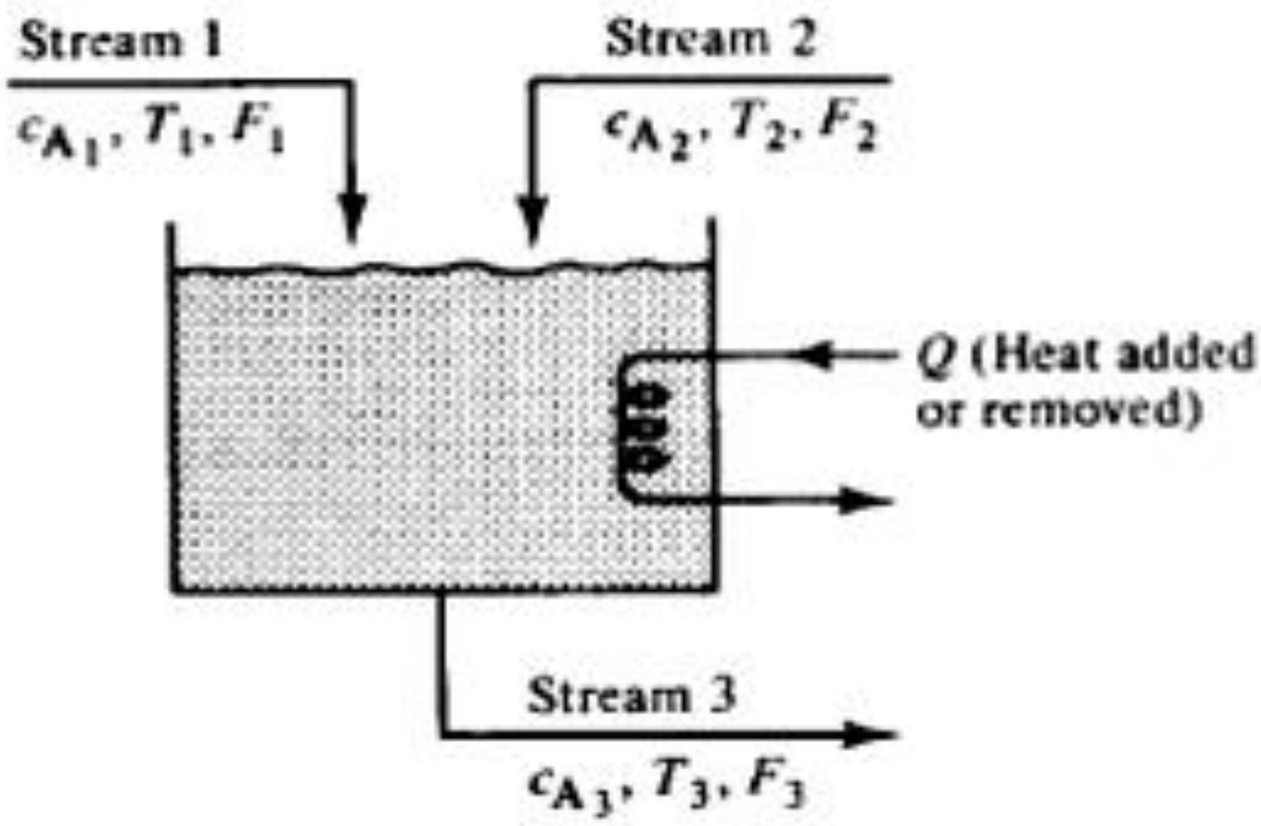

Fig. 1

(10 + 2) = 12

Group - C

4. (a) The set point of the control system shown in Fig.2 has given a step input of 0.1 unit. Determine
   - (i) the maximum value of C
   - (ii) the offset
   - (iii) the period of oscillation
   - (iv) the ultimate value of C.

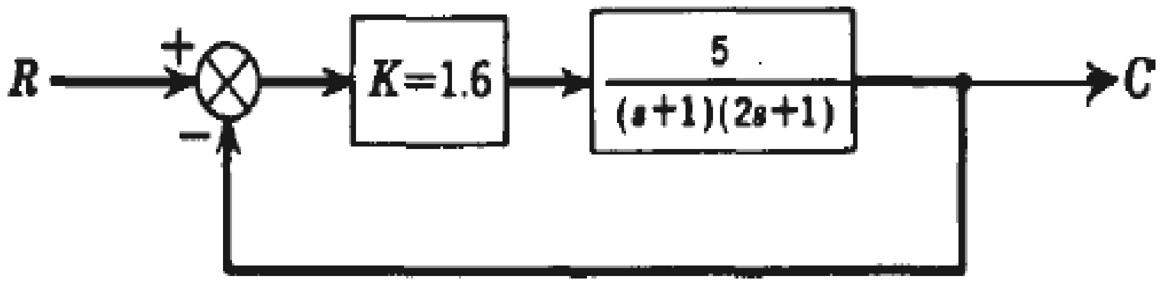

Fig. 2

[(CO2)(Evaluate /HOCQ)]

(b) Mention the difference between corner frequency and cross-over frequency.

[(CO3)(Analyze/IOCQ)]

9 + 3 = 12

5. (a) For the control system shown in Fig. 3,
   - (i) Obtain the characteristic equation.
   - (ii) Determine the value of K above which the system is unstable.
   - (iii) Determine the value of K for which two of roots are on imaginary axis, and determine the values of the imaginary roots and other roots.

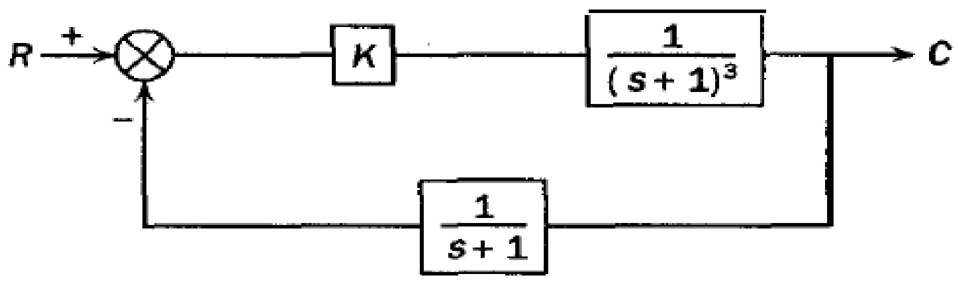

Fig.3

[(CO3)(Evaluate/HOCQ)]

(b) State the Bode stability criterion. [(CO3)(Remember/LOCQ)]

(2 + 4 + 4) + 2 = 12

Group – D

6. (a) With the aid of Bode diagram, prove that dead time will be the source of instability of the system with following open loop transfer function.

$$G_{OL} = \frac{Ke^{-t_d s}}{0.5s+1}$$

Plot the Bode diagram (amplitude ratio and phase shift versus frequency) with t_d values 0.1 and 1. [(CO3,CO4)(Evaluate/HOCQ)]

(b) Sketch the trends of the flow capacity characteristic of a control valve for various stem positions. [(CO4)(Remember/LOCQ)]

8 + 4 = 12

7. (a) A process model for a system is given as

$$\tilde{G}(s) = \frac{Ke^{-7s}}{s}$$

   - (i) Calculate the PI and PID controller settings for K=0.2 and τ_c=8 and 15 using the IMC tuning method

(ii) Determine the largest value of K that results in a stable closed-loop system for each controller. [(CO3,CO4)(Evaluate/HOCQ)]

(b) In an IMC controller, show that the feedback controller transfer function is given by $G_c = \frac{G_c^*}{1-G_c^*\tilde{G}}$ where G_C^* is the IMC controller transfer function. [(CO4)(Analyze/IOCQ)]

(4 + 3) + 5 = 12

Group - E

8. (a) If the input to a first order instrument of time constant 20 s is 100 sin ωt,
   (i) What maximum value of frequency will lead to dynamic error limited to ±10%?
   (ii) If input frequency is kept at that value, what should be the reduced time constant to bring the dynamic error to ±5%?
   (iii) Obtain the time lags in both cases. [(CO5)(Evaluate/HOCQ)]

   (b) Discuss the working principle of a resistance temperature detector with diagram. [(CO5)(Understand/LOCQ)

6 + 6 = 12

9. (a) "Magnetic flowmeters work on the principle of Faraday's law of electromagnetic induction". Justify the statement by explaining the working principle of a magnetic flowmeter with a diagram. [(CO5) (Analyze/IOCQ)]

   (b) Discuss the advantages offered by an inclined tube manometer over a U-tube manometer. [(CO5)(Analyze/IOCQ)]

   (c) "Rotameter is a flowmeter operating on the variable area principle". Justify the statement. [(CO5)(Analyze/IOCQ)]

5 + 4 + 3 = 12

Cognition Level	LOCQ	IOCQ	HOCQ
Percentage distribution	12.53	45.8	41.67

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