[3 Hours] **[Total Marks: 80]**

Instructions to the candidates if any: -

1. Question No 1 is compulsory
2. Attempt any three questions from the remaining five questions
3. Assume suitable data wherever necessary
4. Figures to the right indicates full marks

Q. No, 1

a. Discuss the needs of controlling a chemical process. [05]

b. Derive and plot response of a first order system to a step input of magnitude M. [05]

c. The following reaction takes place in a CSTR at a constant temperature

$$3A \xrightarrow{k_1} B \qquad -r_A = k_1 C_A^3$$

where C_A is the concentration of A in the reactor. Derive the transfer function relating the outlet concentration C_A to the inlet concentration C_{Ai}. Assume volume is constant [05]

d. Discuss in brief control valve characteristics. [05]

Q. No, 2

a. Derive the dynamic model for stirred tank heating process with variable hold-up. [10]

b. With usual notation derive closed loop transfer function for servo and regulator problem. [10]

Q. No. 3

a. A stirred-tank reactor has an internal cooling coil to remove heat liberated in the reaction. A proportional controller is used to regulate coolant flow rate so as to keep the reactor temperature reasonably constant. The controller has been designed so that the controlled reactor exhibits typical under damped second-order temperature response characteristics when it is disturbed, either by feed flow rate or by coolant temperature changes.

i. The feed flow rate to the reactor changes suddenly from 0.4 to 0.8 kg/s, and the temperature of the reactor contents, initially at 100 °C, changes eventually to 104^0C. What is the gain of the transfer function (under feedback control) that relates changes in reactor temperature to changes in feed flow rate? (Be sure to specify the units.).

ii. The operator notes that the resulting response is slightly oscillatory with maxima estimated to be 104.5^0C and 104 ^{0}C occurring at times 1000 and 3060 s after the change is initiated. What is the complete process transfer function?

iii. The operator failed to note the rise time. Predict *t*, based on the results in (i) and (ii). [10]

b. Two streams w_1 and w_2 each at a constant density of 900 kg/m^3, and carrying solute of mass fraction x_1 and x_2 respectively, enter a continuous stirred tank of 2m^3 capacity. At steady-state, w_{1s}=600 kg/min, w_{2s}=300 kg/min, x_{1s}=0.4, and x_{2s}=0.75. Suddenly the inlet flow rate w_2 decreases to 115kg/min and remains there. Determine an expression for the mass fraction of the solute *x(t)*. Assume that liquid hold up is constant. [10]

Q. No. 4

a. Consider a feedback control system in which $G_C(s) = K_C$, $G_V(s) = \frac{1}{3s+1}$, $G_P(s) = G_d(s) = \frac{1}{5s+1}$ and $G_m(s) = 1$. Determine the range of K_C for which the system is closed loop stable. [10]

b. Discuss frequency response of a first order system. [10]

Q. No. 5

a. Write short notes on the following

i. Gain and Phase margin

ii. Nyquist Stability criterion [10]

b. For a unit feedback system $G(s) = \dfrac{K}{s(s+4)(s+2)}$ Sketch the root locus showing all details on it. Comment on the stability of the system. [10]

Q. No. 6

a. Discuss feedback control of a first order system using a proportional controller. You may ignore the dynamics of other elements in the closed loop. [10]

b. Write short notes no the following

i. Cohen Coon tuning method

ii. Ziegler Nichols tuning method. [10]