[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 following with an example [05]
   i. Disturbance variable
   ii. Controlled variable
   iii. Manipulated variable

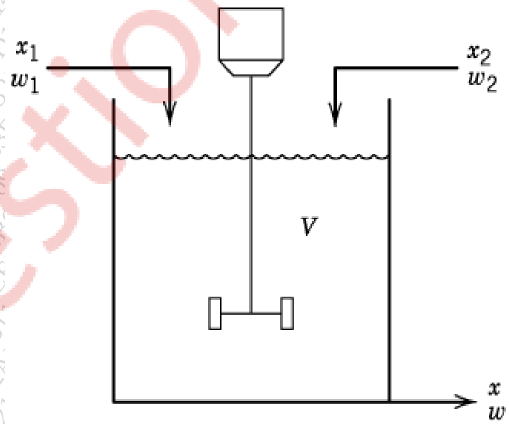
b. Derive the transfer function for a parallel form of PID controller. [05]

c. Explain why mercury in glass thermometer is a first order system. [05]

d. Write a short note on Nyquist stability criterion. [05]

Q. No. 2

a. Derive the dynamic model for the isothermal blending process which is shown in the following figure.



w_1, w_2 and w are the mass flow rates.

x_1, x_2 and x are the mass fraction of component A in w_1, w_2 and w respectively.

V is the volume of the liquid in the tank. [10]

b. A composition sensor is used to continuously monitor the contaminant level in a liquid stream. The transfer function of the sensor is given as-

$$\frac{C_m(s)}{C(s)} = \frac{1}{17s+1}$$

Where C is the deviation in the actual concentration and C_m is the deviation in the measured value. The process is at steady state initially, with the contamination at 6 ppm, when the input starts increasing as $c(t) = 5 + 0.3t$, where t is in sec.an alarm sounds if the measured value exceeds the environmental limit of 9 ppm. Both c and c_m are 6 ppm at initial steady state. After the actual concentration exceeds the limit, how long will it take for the alarm to sound? [10]

Q. No. 3

a. The model of the electrically heated stirred-tank system is given by the following equations

$$\frac{dT}{dt} = \frac{w}{\rho V}(T_i - T) + \frac{h_E A_E}{\rho V C_P}(T_E - T)$$

$$\frac{dT_E}{dt} = \frac{Q}{m_E C_{PE}} - \frac{h_E A_E}{m_E C_{PE}}(T_E - T)$$

i. Derive transfer functions relating changes in outlet temperatures T to changes in two input variables: the heater input Q and inlet temperature T_i.

ii. Show how these transfer functions are simplified when negligible thermal capacitance of the heating element is assumed. [10]

b. With usual notations, derive the closed loop transfer function for a servo problem [10]

Q. No. 4

a. A single tank process has been operating for a long period of time with the inlet flow rate q_i equal to 30.4 lit/min. After the operator increase the flow rate suddenly at $t = 0$, by 16 %, the change in the liquid level in the tank occurs as shown in the following table.

t (min)	0	0.2	0.4	0.6	0.8	1.0	1.2
□ (cm)	5.50	5.75	5.93	6.07	6.18	6.26	6.32
t (min)	1.4	1.6	1.8	2.0	3.0	4.0	5.0
□ (cm)	6.37	6.40	6.43	6.45	6.50	6.51	6.52

Assume that the process dynamics can be described by a first order model. Calculate the steady state gain and the time constant by using

i. From the time required for the output to reach 63.2 % of the total change.

ii. From the slope of the fraction incomplete response curve.

iii. From the initial slope of the response curve. [15]

b. Discuss the characteristic of a control valve. [05]

Q. No. 5

a. Discuss general stability criterion for stability of a closed loop system. [10]

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

Q. No. 6

a. Discuss frequency response of a second order system. [10]

b. Consider the following T.F. Of a first order processes with dead time

$$G_P(s) = \frac{2e^{-0.5s}}{(\tau s + 1)}$$

A proportional controller is used to complete negative feedback loop with the process. When the controller gain is set equal to 2.5, the phase margin is found to be 30^0. What is the value of process time constant? What is the corresponding gain margin? [10]

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