Ref No: - Ex/ChE/PC/B/T/322/2022

B.E. CHEMICAL ENGINEERING THIRD YEAR SECOND SEMESTER 2022

PROCESS DYNAMICS AND CONTROL

Time : Three hours Full Marks : 100

Question 6 is compulsory
Answer any three from the rest.
Examinees may carry Table of Laplace Transforms

1. You are required to estimate the volumetric flow rate, q (L min^{-1}), through a constant-volume mixing tank (V = 1000 L) in which an aqueous solution, containing a certain solute, is mixed. You can measure only the solute concentrations C_i (in inflow) and C (in outflow). Somebody suggests that you momentarily increase C_i (and then instantaneously bring it back to its earlier steady value) and observe how C changes subsequently:

t (min)	:0	2	4	8	12	16	20	30	40
$C-C_s$ (g/L)	:1	0.8187	0.6703	0.4493	0.3012	0.2019	0.1353	0.0498	0.0183

Based on the above data (where C_S is the steady value) estimate, if possible, 'q'.
(20 marks)

2. Derive, and compare the transfer function models of isothermal CSTR with liquid phase reaction for the cases of 1st order and 2nd order kinetics respectively.
(20 marks)

3. Examine the effect of controller dynamics on overall process dynamics with regard to order of dynamics, offset and speed of response of the controlled process by considering a first-order process with Proportional and Proportional-Integral modes of control action separately. *(20 marks)*

4. Consider a control system where $G_p = 10/[1+5s]$; $G_v = 0.5/[1+1.5s]$ and a sensor-transmission combine is present. Obtain the optimum range of values of the gain for a P controller for each of the following cases regarding the dynamics of the sensor-transmission combine, separately by Routh Analysis and Frequency Response to the extent possible.

   (a) Zero-order element: $G_m = 2$.
   (b) First-order element: $G_m = 2 /[1+0.5s]$ *(20 marks)*

5. The outflow from a storage tank (A=4 m^2, maximum liq. height = 5 m) is forcibly constrained at 0.02 m^3/s. At a certain "steady state", tank fluid level was 2 m. The inflow rate is suddenly decreased by 10%.
   (a) How is the tank fluid level affected? Does it reach a final 'steady' value?
   (b) Redo the above problem when there is no constraint on the tank outflow.
(20 marks)

PLEASE TURN OVER

6. Compare Ziegler-Nichol's controller settings (based on the Bode stability criterion and Frequency Response) and Cohen-Coon settings (based on the Process Reaction Curve approximated by a FOPDT model $G_{PRC} = \frac{K_P}{1+\tau s} e^{-\tau_D s}$ for a PI controller used in a control system where $G_p=1/[1+5s]\,[1+2s]$; $G_m=1/[1+10s]$ and a very fast FCE. State all necessary assumptions. Also redo the problem, to the extent possible, if the measuring element is also very fast i.e.; with negligible dynamics. *(40 marks)*

Zeigler-Nichol's Optimum Controller Setting Fomulae:

Control mode	$G_c(s)$	K_c	τ_I	τ_D
P	K_c	$0.5K_u$		
PI	$K_c(1+1/\tau_I s)$	$0.45\ K_u$	$P_u/1.2$	
PID	$K_c(1+1/\tau_I s+\tau_D s)$	$0.6\ K_u$	$P_u/2.0$	$P_u/8.0$

Cohen-Coon's Optimum Controller Setting Fomulae:

Process Transfer function : FOPTD model: $\frac{K_p}{1+\tau s} e^{-\tau_D s}$

Control mode	K_c	τ_I	τ_D
P	$(1/K_p)(T/T_d)(1+T_d/3T)$		
PI	$(1/K_p)(T/T_d)(9/10+T_d/12T)$	$T_d(30+3T_d/T)/(9+20T_d/T)$	
PID	$(1/K_p)(T/T_d)(4/3+T_d/4T)$	$T_d(32+6T_d/T)/(13+8T_d/T)$	$T_d(4)/(11+2T_d/T)$
PD	$(1/K_p)(T/T_d)(5/4+T_d/6T)$		$T_d(6-2T_d/T)/(22+3T_d/T)$