INDIAN INSTITUTE OF TECHNOLOGY–KHARAGPUR

Mid-Spring Semester 2017-18 (Closed Book)

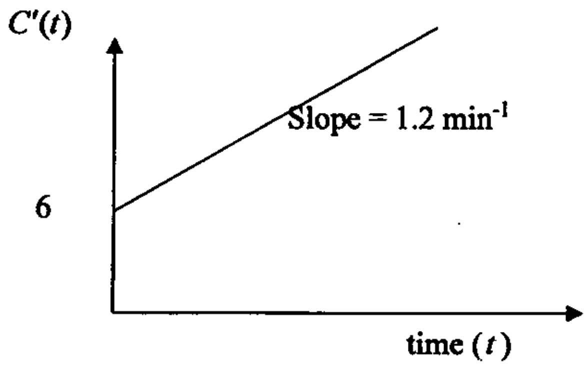
Course No.: CH 61016 | Max. Time: 2 hrs
Course Title: Process Dynamics and Control | Total Marks: 30
Department: Chemical Engineering

Answer all questions

Q1. (a) Develop the real PID controller with derivative of output rather than error and its block diagram. **[(1+1)+(1+2)+2+5+2+1=15]**

(b) If $\tau_f = 10\Delta t$ (where, τ_f is the filter time constant and Δt the sampling instant), find the filter factor (f) for a digital first-order filter with deriving concerned correlation.

(c) The input error signal to a PI controller changes stepwise with a magnitude of 2 and the controller output (C') changes initially as shown below:



Find the values of the controller gain (K_C) and integral time constant (τ_I).

(d) Consider a feedback loop having the following transfer functions:

$$G_P = G\,e^{-t_d s} = \frac{e^{-0.5s}}{0.8s+1} \qquad G_m = G_f = 1$$

Although the model is perfectly known (i.e. $G = G'$), the dead-time (t_d) value is wrongly determined as 0.45 min. Discuss the impact of dead-time on the effectiveness of smith predictor when the process operates under P-only controller with $K_C = 30$.

(e) Configure the cascade control scheme for the bottom composition loop of a distillation column.

(f) One type of ratio controller has divider, another one has ratio station; which one is better and why?

[Please Turn Over]

Q2. Consider the dynamic model of a jacketed stirred tank heating system where the water temperature (T) in the tank is to be controlled by manipulating the flow rate of hot oil in the jacket (F_j). All other variables are remaining constant at their steady state values.

Parameter and steady state values
$F = 30$ l/m; $Fj = 50$ l/m; $T_i = 15^0$C; $Tji = 93^0$C; $V = 300$ l; $V_j = 30$ l; $\rho C_p = 1$; $\rho_j C_{pj} = 1.384$; $UA = 100$;

$$\frac{dT}{dt} = \frac{F}{V}(T_i - T) + \frac{UA}{\rho C_P V}(T_j - T)$$

$$\frac{dT_j}{dt} = \frac{F_j}{V_j}(T_{ji} - T_j) - \frac{UA}{\rho_j C_{Pj} V_j}(T_j - T)$$

Derive the following for this system: **[1+3+3]**

a) Non-linear state space model
b) Linear state space model
c) Transfer function model

Q3. Consider the transfer function of a system defined by the following equation

$$\frac{y(s)}{u(s)} = g(s) = \frac{6s^3 + 55s^2 + 168s + 168}{s^4 + 12s^3 + 53s^2 + 102s + 72}$$

a) Derive Jordan canonical form of state-space realization for this transfer function
b) Derive observer canonical form of state-space realization for this transfer function **[4+4]**

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