INDIAN INSTITUTE OF TECHNOLOGY KHARAGPUR
Department of Chemical Engineering
2021-22 Spring test #2
Subject: Process Dynamics and Control (CH61016)

Instructions:

1. This test contains questions from the parts instructed by Professor A. N. Samanta as well as Professor P. A. Deshpande. All questions are compulsory.

2. Those who are attempting this test online should use pen-and-paper to solve the problems and scan their sheets to a "single" pdf. Your name and roll number "must" be written with a pen on your answersheet. Without this mention, the answersheet will not be evaluated.

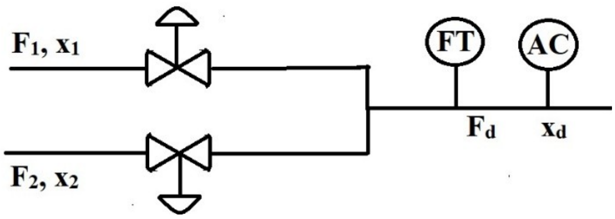
3. Upload your pdf as a response to the assignment **2021-22 Spring test #2 in MS Teams course page**.

4. MS Teams will stop collecting the responses at 10:00 am. No late submission are allowed. Submissions using emails to the instructor will not be checked this time under any circumstance. So please do the time management properly.

5. If you are writing this test offline, then use pen-and-paper to write your responses in the sheets provided to you and submit them back to the instructor at 10:00 am.

6. MATLAB can be used only for arithmetic operation and matrix operation/inversion.

Q1. Consider the blending process in figure below:



What should be the best input/output pairing using RGA analysis for x_1=0.8 mol/liter, x_2=0.1 mol/liter and x_d = 0.5 mol/liter. Assume constant density. **[3]**

Q2. Consider the incomplete RGA given below

$$\Lambda = \begin{bmatrix} a & 0.15 & b & -0.09 \\ -0.01 & c & 0.29 & x \\ d & 3.31 & 0.27 & e \\ 0.22 & f & g & 1.84 \end{bmatrix}$$

a) What will be the values of unknown a to f if x = 1.15.
b) Can we complete the RGA if x is not known? **[3.5+0.5=4]**

Q3. The transfer function model of a process is given below:

$$\begin{bmatrix} y_1 \\ y_2 \end{bmatrix} = \begin{bmatrix} \frac{1.318 e^{-3s}}{20s+1} & \frac{-e^{-s}}{3s} \\ \frac{0.38(18s+1)e^{-2s}}{(27s+1)(10s+1)} & \frac{0.36}{s} \end{bmatrix} \begin{bmatrix} u_1 \\ u_2 \end{bmatrix}$$

a) Calculate RGA for the system
b) Design a physically realizable dynamic decoupler for the process using Generalized approach

[2+2=4]

Q4. Consider the state-space model of drug concentration in blood and tissues as

$$\frac{dx_1}{dt} = -0.4x_1 + 0.09x_2 + 0.005x_3 + 0.1u$$

$$\frac{dx_2}{dt} = 0.2x_1 - 0.2x_2$$

$$\frac{dx_3}{dt} = 0.04x_1 - 0.005x_3$$

$$y = x_1$$

a) Design a state feedback controller equation for regulatory control using Bass-Gura Method. The desired pole location is [-0.5, -0.15, -0.1].
b) Design reduced order observer equations for the states $x_2 \wedge x_3$ using ackermann's formula with desired observer pole location at [-0.05, -0.5]. **[4+5=9]**

Q5. Consider a general first order process described by the following equation:

$$a_1 \frac{dy}{dt} + a_0 y = bu(t)$$

Determine the difference between the time period of oscillation of a sinusoidal

input function and the response of the system to it in the limit $a_0 \rightarrow 0$. Show all the steps in detail. **[8]**

Q6. Consider a general (p,q) order system with a transfer function whose numerator and denominator polynomials are completely factorisable. If the system is subjected to a step input then
(a) show that the stability of the system is dependent only upon the poles and not the zeros of the transfer function,
(b) the initial slope of the response is zero for p-q>1,
(c) comment upon the stability from the magnitudes and signs of the poles.

[4+4+4]