BIRLA INSTITUTE OF TECHNOLOGY & SCIENCE PILANI

SECOND SEMESTER 2022-2023

CHE F342: Process Dynamics& Control

Comprehensive Examination (CLOSE BOOK) **Date: 22.05. 2022**

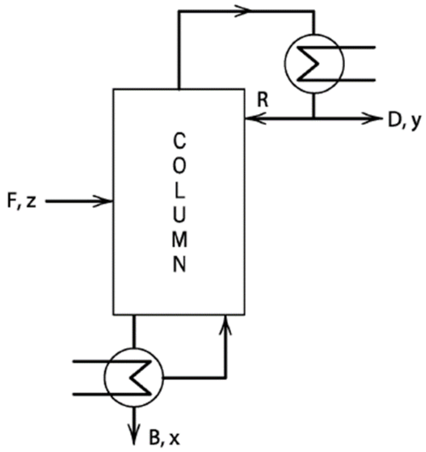
Duration: 9:30 - 12:30 PM **Max. Marks: 120**

Name: **Roll No:**

PART A: Answer the questions in the space provided ***(Write the final answer only; No partial marking, use the last pages of the answer booklet for rough work)***

1. The distillation column shown in the drawing is used to distill a binary mixture. Symbols *x*, *y*, and *z* denote mole fractions of the more volatile component, while *B*, *D*, *R*, and *F* represent molar flow rates. It is desired to control distillate composition y despite disturbances in feed flow rate *F*. All flow rates can be measured and manipulated with the exception of *F*, which can only be measured. A composition analyzer provides measurements of y.

   Propose a FBC schematic diagram (connect the lines in Fig.)

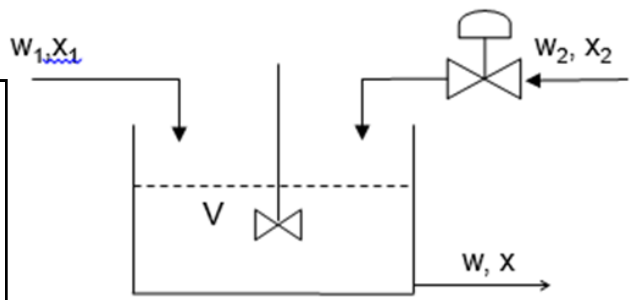


2. Propose an FFC schematic diagram for the above system.

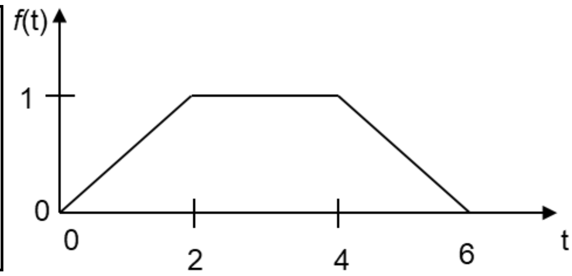
3. Perform the degree of freedom analysis.

Degree of freedom (N_F)=

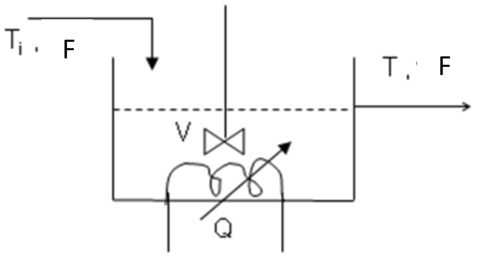
MV & CV pairing:



4. Find F(s) if F(t) is given by



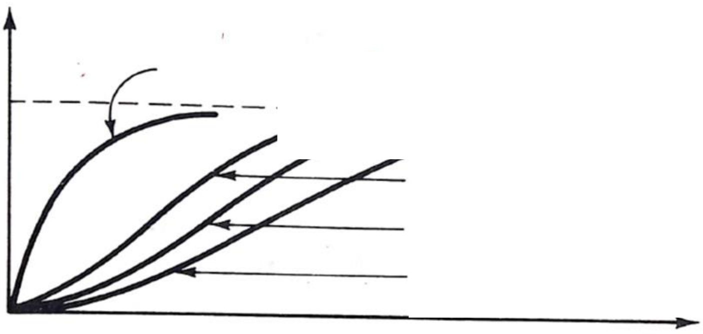
5. For the system shown in Fig. Develop an open loop block diagram (Assume *F* is constant)



6. The closed-loop transfer function of a control system is given by $\frac{C(s)}{R(s)} = \frac{2(s-1)}{(s+2)(s+1)}$. For a unit step input, the output response is.

7. Compare the responses for a unit step change in input variable for a first-order thermometer with τ=0.1, 1, and 10 sec. (plot all responses in a single plot and name the axis)

8. Identify the responses of a single tank, two-tank interacting, two-tank non-interacting, and 4- tanks non-interacting shown in Fig. (Assume all tanks are first order).

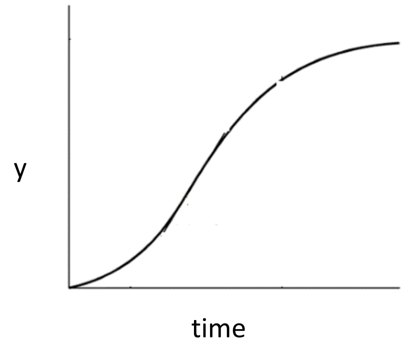


9. Write the response equation of a second-order under-damped system for a unit step change in the load variable.

10. Using Skogestard's Half-Rule Method, approximate G(s) into FOPTD

$$G(s) = \frac{K(-0.1s+1)}{(5s+1)(3s+1)(0.5s+1)}$$

11. Show the calculation of parameters for FOPTD using the tangent method. The plot shows the process reaction curve.



12. Define the Bode stability criterion and safety limits for Gain margin (GM) and Phase margin (PM)

GM= ; PM=

13. A step change of magnitude 4.0 is introduced into a system having the transfer function $G(s) = \frac{10}{S^2+1.6S+4}$. Determine

Overshoot (%): Maximum value of Y(t):

14. Draw a schematic using ratio control for controlling the stoichiometric reactant flows into an NH_3 synthesis reactor.

15. Define proportional band.

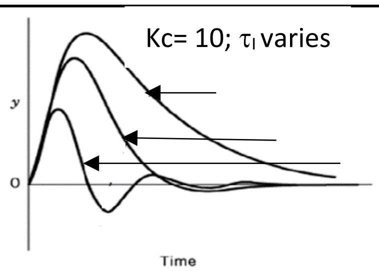
16. Write the mathematical forms to eliminate proportional and derivative kicks in a PID controller.

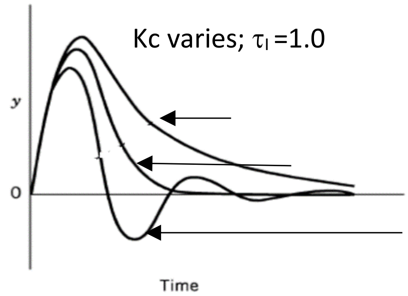
17. Recommend control valves: *Air-to-Close* and *Air-to-Open* for heating and cooling applications.

For Heating:

For cooling:

18. The plot shows the responses of a PI-controlled system for a load change at three different values of τ_I (0.1, 1, and 10) and K_c (10, 50, 100). Indicate these values in the plot.





19. Write the ZN settings for

For PI: K_c= ; τ_I =

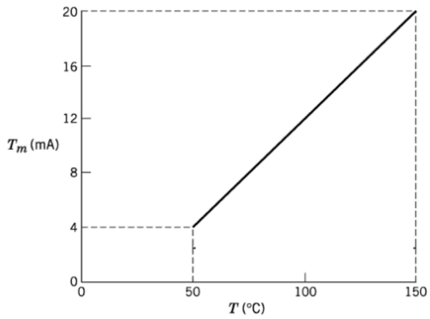
For PID: K_c= ; τ_I = ; τ_D =

20. Calculate the *Zero, Span* and *Gain* of the instrument of the following.

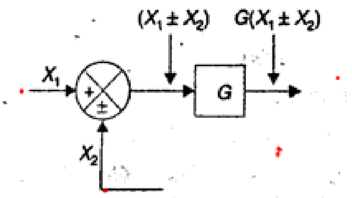
Zero=

Span=

Gain=



21. Draw the equivalent to the following using “moving summing point after a block.”



22. Consider a process, *Gp = 0.2/(-s + 1),* that is open-loop unstable and Why ?. If *Gv = Gm = 1*, determine whether a proportional controller can stabilize the closed-loop system. If Yes/ No, justify.

23. Using the Direct Synthesis Method, design a feedback controller for a purely first-order process

Kc= ; τ_I = ; τ_D =

$$\tilde{G} = \frac{K}{\tau s + 1}$$

24. If the process is given by $\bar{G}$(s), then find out the controller parameters by IMC method (use $e^{-\theta s}$= 1-θs)

Kc= ; τ_I = ; τ_D =

$$\tilde{G} = \frac{Ke^{-\theta S}}{(\tau S + 1)}$$

25. The unit impulse response for a unity feedback control system is given by $c(t)= -te^{-t}+2e^{-t}$. The open-loop transfer function equal to

26. The closed-loop transfer function of a control system is given by $\frac{C(s)}{R(s)} = \frac{1}{s+1}$. For the input $R(t)= Sint$, the steady state value of $C(t)$ is

27. The forward path for a unity feedback P- controlled system is given by $G(s) = \frac{1}{(s+1)(s+6)}$. For a given unit step change in set point and load variable, then off-set is

For set point: For load change:

28. By a suitable choice of parameter Kc, the unity feedback system with a forward transfer function $G(s) = \frac{Kc}{s(s+2)(s+8)}$, can be made to oscillate continuously at a *Kc* of

29. Given a system represented by equations $\tilde{x} = -\begin{bmatrix} 0 & 1 \\ -2 & -3 \end{bmatrix} x + \begin{bmatrix} 0 \\ 1 \end{bmatrix} u \quad and\ y = [1\ 0]x$. The equivalent transfer function representation G(s) of the system is

30. A system is described by the state equation $\begin{bmatrix} \dot{x}1 \\ \dot{x}2 \end{bmatrix} = \begin{bmatrix} 2 & 0 \\ 0 & 2 \end{bmatrix} \begin{bmatrix} x1 \\ x2 \end{bmatrix} + \begin{bmatrix} 1 \\ 1 \end{bmatrix} u$. The state transition matrix of the system is

Part B **Marks: 60 M**

Note: *write your answers on a fresh page at the beginning of each question*

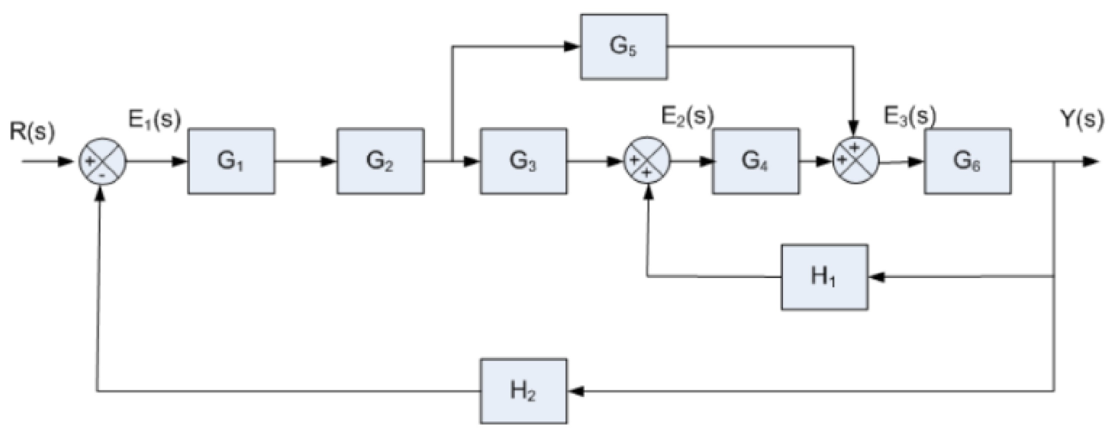
Don't skip any steps; highlight the final answers with a BOX.

1. A composition analyzer is used to measure the concentration of a pollutant in a wastewater stream. The relationship between the measured composition C_m and the actual composition C is given by the following transfer function (in deviation variable form): $\frac{C_m'(s)}{C'(s)} = \frac{e^{-\theta s}}{\tau S+1}$. where θ = 2 min and τ = 10 min. The nominal value of the pollutant is C = 5 ppm. A warning light on the analyzer turns on whenever the measured concentration exceeds 25 ppm. Suppose that at time t = 0, the actual concentration begins to drift higher, $C(t) = 5 + 2t$, where C has units of ppm and t has units of minutes. At what time will the warning light turn on? [10 M]

2. A first-order system is modeled as $\tau_p \frac{dy}{dt} + y = K_p u + K_d d$, where τ_p is the time constant of the process, K_p is process gain, K_d is disturbance gain, y is the output of the process, d is the load variable, and u is manipulated variable. If the process is controlled by a P-controller using G_v(FCE)= G_m(sensor)= 1
   a. Calculate the closed loop time constant, and what do you infer from the equation?
   b. Determine the closed-loop response equation for simultaneous change in setpoint and load change.
   c. Calculate the off-sets for a unit step change in servo and regulatory mechanisms. [8 M]

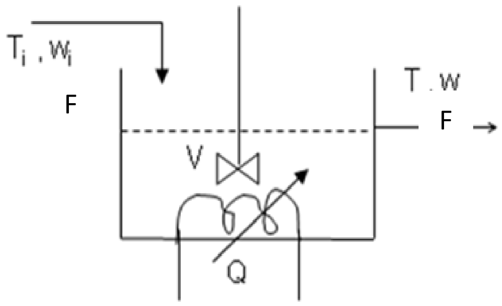
3. Determine the root locus of the system whose open loop gain is $G(s)H(s) = \frac{K}{S(S^2+6S+25)}$. Provide all the steps. [10 M]

4. Determine the Y(s)/ R(s)



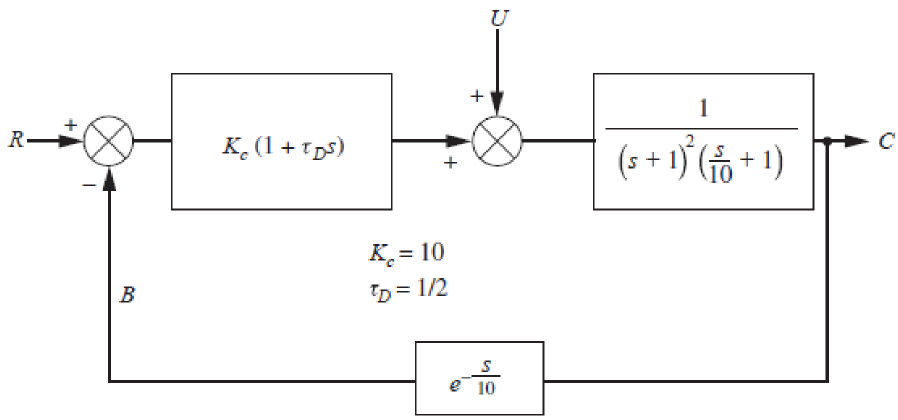
[10 M]

5. Design a static and dynamic feed-forward controller for the system shown in Fig. and show the block diagram representation for each controller. (Assume constant holdup, state all your assumptions clearly)



[10 M]

6. i. Plot the Bode diagram for the open-loop transfer function of the control system of Fig. [6 M]



ii. For a system with Gc=Kc, Gv=1, Gm=1, $Gp(s) = \frac{e^{-0.1s}}{0.5S+1}$. design the controller with the phase margin of 30°. Check whether the controller is stable when 50% error is made in dead time calculation. [6 M]

All the Best