KATHMANDU UNIVERSITY
End Semester Examination [C]
April/May, 2023

Marks Scored:

Level : B.E.
Year : III
Exam Roll No. :

Time: 30 mins.

Course : CHEG 302
Semester : I
F. M. : 10

Registration No.:

Date : 03. May-023

SECTION "A"
[20Q. × 0.5 = 10 marks]

Encircle the most appropriate option.

1. For a MIMO process consisting of 3 inputs & 4 outputs, the total number of transfer functions for the system would be

   a. 3 b. 4 c. 7 d. 12

2. Consider the transfer function $(s) = \frac{K(-0.1s+1)}{(5s+1)(3s+1)(0.5s+1)}$. When approximated as a FOPDT model using Taylor series, the transfer function would become

   a. $\frac{Ke^{-2.1s}}{6.5s+1}$ b. $\frac{Ke^{-3.6s}}{5s+1}$ c. $\frac{Ke^{-2.1s}}{5s+1}$ d. $\frac{Ke^{-3.6s}}{6.5s+1}$

3. For a stirred-tank heater, assume the transfer function between the heater input change $u(t)$ (cal/sec) and the tank temperature change $y(t)$ (°C) can be modeled as $G(s) = \frac{5}{(3s+1)}$. Using the Final Value Theorem, the steady-state response for a unit rectangular pulse change in the heating rate ($U(s) = \frac{1-e^{-s}}{s}$) would be

   a. 0 b. 1 c. ∞ d. -1

4. An overdamped system consists of two first-order processes operating in series ($\tau_1 = 4$, $\tau_2 = 1$). The equivalent values of τ and ζ for this system are respectively

   a. 2 & 1.25 b. 2 & 0.40 c. 1.25 & 2 d. 0.40 & 2

5. A liquid flows through an equal percentage valve at a rate of 2 m^3/h when the valve is 10% open. When the valve is 20% open, the flow rate increases to 3 m^3/h. Assume that the pressure drop across the valve and the density of liquid remains constant. When the valve opens to 50%, the flow rate in m^3/h is

   a. 4.50 b. 6 .00 c. 6.75 d. 10.12

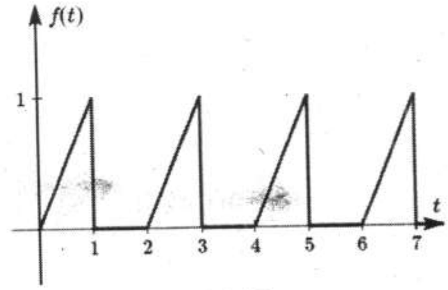
6. A control valve having turndown ratio of 50 follows equal percentage characteristic. The flow rate of liquid through the valve at 40% stem position is 1 m^3/h. The flowrate in m^3/h at 50% stem position if pressure drop across the valve remains unchanged would be

   a. 1.47 b. 1.63 c. 2.45 d. 3.91

7. The overall transfer function for 2 noninteracting capacities in series can be described by $G_0(s) = G_1(s).G_2(s) = \frac{K_{p_1}}{\tau_{p_1}s+1} \cdot \frac{K_{p_2}}{\tau_{p_2}s+1}$. The response for such a system can never be

   a. underdamped b. overdamped
   c. critically damped d. oscillatory

8. Laplace transform of the following periodic function is



a. $\frac{1-e^{-s}-se^{-s}}{s^2}$ b. $\frac{1-e^{-s}-se^{-s}}{s^2(1-e^{-2s})}$

c. $\frac{1-e^{-s}-se^{-s}}{s(1-e^{-s})}$ d. $\frac{1-e^{-s}-se^{-s}}{s^2(1-e^{-s})}$

9. For the Routh array given below, the value of K_c and τ_I for a stable system would

Row 1	*1*	$2 + K_c$
Row 2	2	$\frac{K_c}{\tau_I}$
Row 3	$\frac{2(2+K_c)-\frac{K_c}{\tau_I}}{2}$	*0*
Row 4	$\frac{K_c}{\tau_I}$	

a. $K_c = 100, \tau_I = 0.1$ b. $K_c = 10, \tau_I = 0.5$

c. $K_c = 1000, \tau_I = 0.1$ d. $K_c = 100, \tau_I = 0.2$

10. For an open loop transfer function $G_{OL} = \frac{K_c e^{-0.5s}}{1+\tau_P s}$, the cross-over frequency is given as $\omega_{co} = 17$ rad/min. Considering a gain margin of 1.7, the ultimate value of K_c would be

a. 0.20 b. 4.90 c. 0.59 d. 28.90

11. Match the following

i.	Piezoelectric sensors	A. Liquid level
ii.	Dielectric measurement	B. Viscosity
iii.	Rheometer	C. Temperature
iv.	Radiation pyrometer	D. Pressure

a. i – B, ii – A, iii – D, iv – C b. i – A, ii – D, iii – B, iv – C

c. i – D, ii – A, iii – B, iv – C d. i – D, ii – C, iii – A, iv – B

12. Offset for a unit step change in setpoint for a pure capacitive system using a P – only controller would be

a. 1 b. K_c c. 0 d. ∞

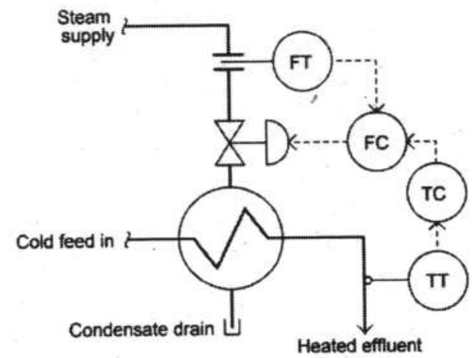
13. A step change of magnitude 4 is introduced into a system having a transfer function $\frac{10}{s^2+1.6s+4}$. The overshoot for the system would be

a. 0.25 b. 0.62 c. 2.50 d. 10

14. The crossover frequency for the open-loop transfer function $\frac{5}{(2s+1)^4}$ would be

a. 5 rad/time b. 2 rad/time c. 0.5 rad/time d. 2.5 rad/time

15. The P&ID shown in the figure shows which control strategy?
   a. Ratio
   b. Feed forward
   c. Cascade
   d. Adaptive gain



16. Choose the most appropriate one.
   a. In cascade control, the master loop is trained before the slave loop.
   b. In cascade control, the controller which is nearest to the final control element is the fastest controller.
   c. Cascade control always increases the sluggishness of the overall response.
   d. Cascade controller is most advantageous when the primary process is significantly faster than the secondary process.

17. A unity negative feedback system has an open-loo transfer function $G(s) = \frac{K}{s(s+1)}$. The gain K for the system to have a damping ratio of 0.25 is
   a. 400 b. 500 c. 250 d. 475

18. A first order system with unity time gain and time constant τ is subjected to a sinusoidal input of frequency $\omega = 1/\tau$. The amplitude ratio o the system is
   a. 1 b. 0.5 c. $1/\sqrt{2}$ d. 0.25

19. The response of the system $G(s) = \frac{s-2}{(+1)(s+3)}$ to unit step input $u(t)$ is $y(t)$. The value of $\frac{dy}{dt}$ at $t \to 0^+$ is
   a. 0 b. 0.5 c. 1.0 d. ∞

20. The proper 'fail safe' status of a valve should always be dictated by
   a. The configuration of the positioner
   b. The controller's tuning
   c. The controller's action (direct or reverse)
   d. The nature of the process

KATHMANDU UNIVERSITY
End Semester Examination [C]
April/May, 2023

03. May.

Level : B.E.
Year : III
Time : 2 hrs. 30 mins.

Course : CHEG 302
Semester : I
F.M. : 40

SECTION "B"
[2Q × 5 = 10 marks]

Attempt *ANY TWO* questions.

1. An electronic PI temperature controller has an output p of 12 mA when the set point equals the nominal process temperature. The controller response to step change in the temperature set point of 2.5 mA (equivalent to a change of 5°F) is shown below

t, s	p, mA
0+	8.0
0-	6.7
20	6.0
60	4.7
80	4.0

a. Determine the controller gain K_c (mA/mA) and the integral time, τ_I. [3]
b. Is the controller reverse-acting or direct-acting? Justify your answer. [2]

2. For the liquid-level control system in Figure 1. the level transmitter has negligible dynamics, while the control valve has a time constant of 10 s. The following numerical values are available:

$$A = 3 \text{ ft}^2$$
$$\bar{q}_3 = 10 \text{ gal/min}$$
$$K_v = -1.3 \text{ gal/min/mA}$$
$$K_m = 4 \text{ mA/ft}$$

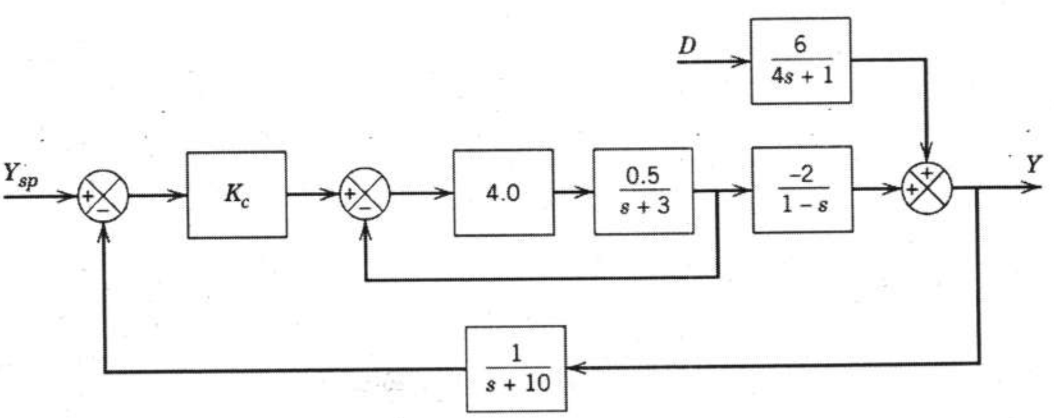


Figure 1

Determine the numerical values of K_c and τ_I for a PI controller that result in a stable closed-loop system. [5]

3. The response of a system to a unit step change in the input (occurring at time 0) is shown in Figure 2.

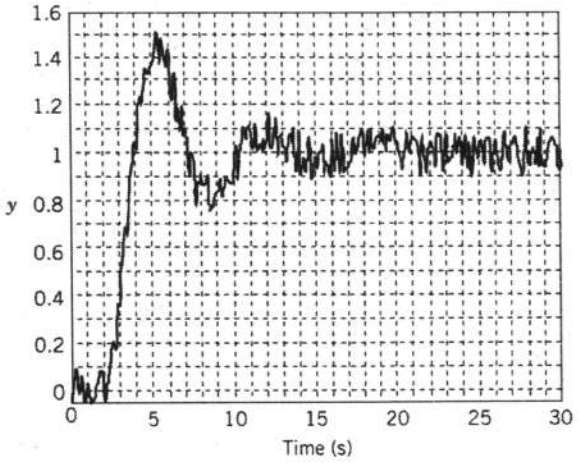


Figure 2

a. Derive a second-order plus time delay model approximation for the system. [3]

b. Provide values for the gain, time constraints, and time delay of the SOPTD model. [2]

SECTION "C"

[3Q × 10 = 30 marks]

Attempt *ANY THREE* questions.

4. Consider the following cascade connection of isothermal reactors as shown in Figure 3. A first-order reaction A → B occurs in both reactors, with reaction rate constant k. The volumes of liquid in the reactors, V, are constant and equal; the flow rates F_0, F_1, F_2 and R are constant. Assume constant physical properties and a negligible time delay for the recycle line.

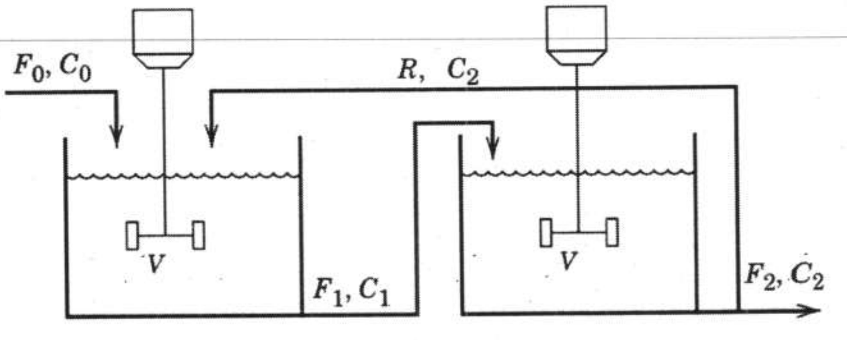


Figure 3

a. Write a mathematical model for this process. [3]

b. Derive a transfer function model relating the output concentration of A, C_2 to the inlet concentration of A, C_0. [2]

c. Verify that, in the limit of no recycle ($R \rightarrow 0$), the transfer function derived in part b is equivalent to the transfer function of the two tanks connected in series. [2.5]

d. Show that when $k = 0$ and a very large recycle flow rate is used (i.e., the limit as $R \rightarrow \infty$), the transfer function derived in part b becomes the transfer function of a single tank that has the volume equal to $2V$ and a gain of one. [2.5]
(Hint: Recognize that $F_1 = R + F_2$ and $F_0 = F_2$)

5. The control system shown in Figure 4 contains a PID controller.

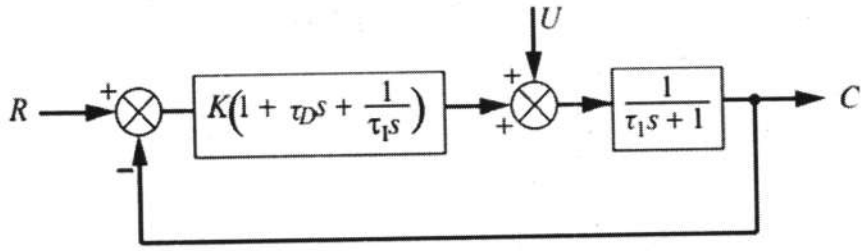


Figure 4

a. For the closed loop, develop formulas for the natural period of oscillation τ and the damping factor ξ in terms of the parameters K, τ_D, τ_I and τ_1. [1]

For the following parts, $\tau_D = \tau_I = 1$ and $\tau_1 = 2$,

b. Calculate ξ when K is 0.5 and when K is 2. [2]

c. Do ξ and τ approach limiting values as K increases, and if so, what are these values? [2]

d. Determine the offset for a unit-step change in load if K is 2. [1]

e. Sketch the response curve (C versus t) for a unit-step change in load when K is 0.5 and when K is 2. [2]

f. In both cases of part e determine the maximum value of C and the time at which it occurs. [2]

6. As a newly hired engineer of the Ideal Gas Company, you are trying to make a reputation in the Process Control Group. However, this objective turns out to be a real challenge with I. M. Appelpolscher as your supervisor. At lunch one day, I.M.A. declares that a simple second-order process with a PI controller will always have a stability upper limit on K_c; that is, K_c is limited for all values of $\tau_I > 0$. His best argument is that the open-loop process with the controller is third order. Furthermore, he claims that any critically damped second-order process will show he is right.

Muttering "au contraire," you leave the table and quickly investigate the properties of

$$G_v G_p G_m = \frac{5}{(10s+1)^2}$$

a. What are the conditions for closed-loop stability for a PI controller? [2]

b. From these conditions, can you find a relationship for τ_I in terms of K_c that will guarantee stability? [3]

c. Show the stability region in a plot of τ_I vs K_c. [2]

d. Do some values of τ_I guarantee stability for all values of K_c? If so, what is the smallest value? [3]

7. Consider the open-loop transfer function $\frac{2e^{-3s}}{(2s+1)(4s+1)}$

a. Draw an approximate root locus diagram by using the rules for manual drawing of root locus for closed-loop system as controller gain is changing from 0 to infinity. [3]

b. Find the approximate critical frequency & the maximum gain. [2]

c. Find optimal controller parameters for a PI controller using Ziegler-Nichols criteria. [3]

d. What is the offset if the setpoint is increased by 2 unit? [2]