KATHMANDU UNIVERSITY
End Semester Examination [C]
December, 2024

Marks Scored:

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

Time: 30 mins.

Course : CHEG 302
Semester : I
F. M. : 10
Date : 20 DEC 2024

SECTION "A"

[20 Q. × 0.5 = 10 marks]

Choose and encircle in the most appropriate option from each set of choices

1. Laplace transformation of $e^{-at}\cos kt\, u(t)$ is
   a. $\frac{k}{(s+a)^2+k^2}$ b. $\frac{s+a}{(s+a)^2+k^2}$ c. $\frac{s-a}{(s+a)^2+k^2}$ d. $\frac{s}{(s+a)^2+k^2}$

2. Which variable deviates the controll variable from set point ?
   a. Manipulated variable
   b. Disturbance variable
   c. Output variable
   d. Reference variable

3. What does a block diagram represent in a control system?
   a. The physical layout of the system's components
   b. The mathematical equations governing the system
   c. The flow of information and functions of each part of the system
   d. The wiring diagram of the control hardware

4. The steady-state gain (K) of a transfer function can be calculated using the steady-state values of input (u) and output (y). Which of the following expressions correctly represents the steady-state gain?
   a. $K=\frac{\Delta u}{\Delta y}$ b. $K=\frac{\Delta y}{\Delta u}$ c. $K=\Delta u - \Delta y$ d. $K=\Delta y - \Delta u$

5. The input change described as a rectangular pulse can be mathematically represented by the equation:
   a. $U_{Rp}(t) = \begin{cases} 0 \text{ for } t < 0 \\ h \text{ for } 0 \le t < t_w \\ 0 \text{ for } t > t_w \end{cases}$
   b. $U_{Rp}(t) = \begin{cases} 1 \text{ for } t < 0 \\ h \text{ for } 0 \le t < t_w \\ 0 \text{ for } t > t_w \end{cases}$
   c. $U_{Rp}(t) = \begin{cases} h \text{ for } t < 0 \\ 1 \text{ for } 0 \le t < t_w \\ 0 \text{ for } t > t_w \end{cases}$
   d. $U_{Rp}(t) = \begin{cases} 1 \text{ for } t < 0 \\ h \text{ for } 0 \le t < t_w \\ 1 \text{ for } t > t_w \end{cases}$

6. In chemical engineering, what is the primary way second-order systems are typically encountered?
   a. From inherently second-order processes that exist independently
   b. From combining two first-order systems in parallel
   c. From adding a controller to a first-order process
   d. From processes that do not require control systems

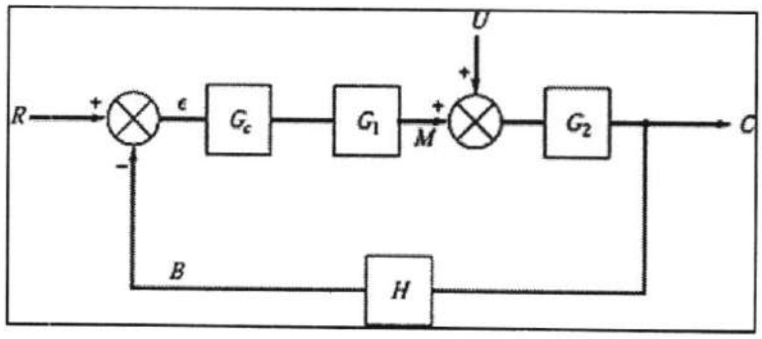
7. When damping co-efficient (ξ) is greater than 1 then response of the system is
   a. Overdamped b. Critically damped c. Under damped d. Undamped

8. Which of the following best describes the function of negative feedback in the control system?
   a. Negative feedback adjusts the control element to increase the error until T_m surpasses T_R
   b. Negative feedback causes the controller to increase the flow of heat to the system when the error decreases.
   c. Negative feedback ensures the control element reduces the error so that T approaches T_R
   d. Negative feedback results in an inherently unstable system due to the addition of T_R and T_m

   Where, T: Controlled variable, T_R: Set point, T_m: Measured variable

9. The output pressure of a pneumatic proportional controller goes from 3 psig (valve fully closed) to 15 psig (valve fully open) as the measured temperature goes from 65 to 77 °F with the set point held constant. What is the controller gain K_c?
   a. 1 b. 2 c. 3 d. 4

10. In a basic single-loop control system:



   The series of blocks between the comparator and the controlled variable is called:
   a. Feedback path b. Forward path c. Control loop d. Transfer function

11. Bode diagram is a plot of
   a. log (AR) vs. φ
   b log (AR) vs. (ω) and log (φ) vs. (ω)
   c. AR vs. log (ω) and (φ) vs. log (ω)
   d. log (AR) vs. log (ω) and (φ) vs. log (ω)

12. Final control element is
   a. Valve b. Switch c. Signal d. Regulator

13. Driving element in control system
   a. Transducer b. Transmitter c. Pneumatic valve d. Strain gauges

14. The approximation of dynamic behavior of the composition sensor-transmitter can be made by considering
   a. A first-order transfer function
   b. A second-order transfer function
   c. A third-order transfer function
   d. A zero-order transfer function

15. Which of the following controllers has minimum offset?
   a. P-Controller b. P-I Controller c. P-D Controller d. P-I-D Controller

16. Feedback controller account for __________ changes.
   a. Set point b. Load c. Gain d. Offset

17. The relation between flow and stem position (or valve-top pressure) for a valve installed in a process line is called the
   a. Inherent valve characteristic
   b. Effective valve characteristic
   c. Flow coefficient
   d. Valve gain

18. In a closed-loop control system, when the time constant of the closed-loop system (τ_1) is smaller than that of the stirred tank (τ), feedback control speeds up the response. For a unit-step change in the set point, the ultimate value of temperature T' (∞) approaches:

a. 1 b. $K_cA/(1 + K_cA)$ c. 0 d. K_cA

Where K_c and A have usual meanings.

19. Which of the following statements is true regarding the open-loop transfer function (GH)?
    a. GH relates the measured variable B to the set point R when the loop is closed.
    b. GH is the product of all transfer functions in the loop, including feedback.
    c. GH relates the measured variable B to the set point R when the feedback loop is disconnected.
    d. GH is used only in systems with a single feedback loop.

20. Which of the following is not the feature of modern control system?

a. Quick response b. Accuracy c. Correct power level d. No oscillation

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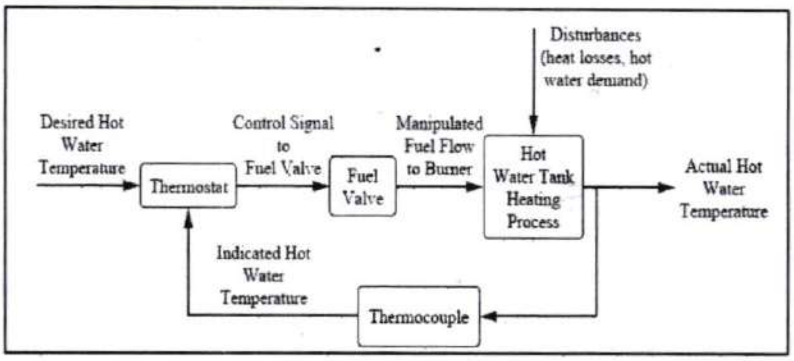
SECTION "B"
[4 Q. × 10 = 40 marks]

Attempt *ANY FOUR* questions.

1. a. From the block diagram of hot water heating system (given below), please explain the functions of each controller. [5]



b. In the chemical mixing process described, the system initially operates at steady state with flow rates of 10 L/min for Stream 1 and 20 L/min for Stream 2. The concentration of A in Stream 1 is $C_{A1} = 1$ g/L and in Stream 2, $C_{A2} = 4$ g/L. The total flow rate leaving the mixing tee is $v_3 = 30$ L/min, and the concentration entering the heating vessel is initially $C_{A3} = 3$ g/L. At 3:00 PM, an operator error switches the flow rates of Streams 1 and 2, making $v_1 = 20$ L/min and $v_2 = 10$ L/min. Assume the volume of the heating vessel is $V = 150$. Using an unsteady-state mass balance, calculate the concentration $C_A(t)$ of A in the heating vessel at 3:30 PM, i.e., after 30 minutes of operation under the new flow conditions. Assume perfect mixing in the heating vessel. [5]

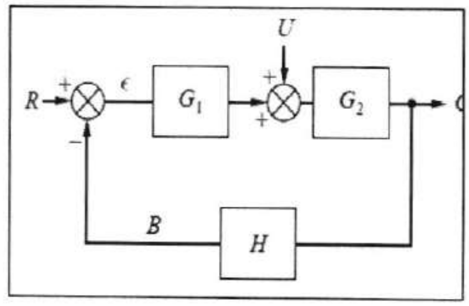
2. c. Derive transfer function of any first order system in process control and instrumentation? [5]

d. A stirred-tank heating system is used to preheat a reactant containing a suspended solid catalyst at a constant flow rate of 1000 kg/h. The volume in the tank is 2 m^3, and the density and specific heat of the suspended mixture are, respectively, 900 kg/m^3 and 1 cal/g °C. The process initially is operating with inlet and outlet temperatures of 100 °Cand 130 °C, respectively. The time required to attain the 86, 95, 98 and 99 % response following a step change of any magnitude in heater input is 2τ, 3τ, 4τ and 5τ, respectively. The steady-state energy input is 3×10^7 cal/h. The transfer function is [1+2+2]

$$T'(s)=\frac{1/wC}{\frac{m}{w}s+1}Q'(s)+\frac{1}{\frac{m}{w}s+1}T_i'(s)$$

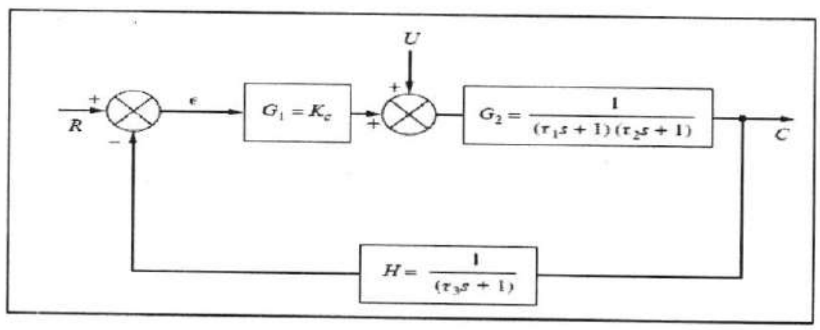
i. What are the values of K and τ?
ii. If the heater input is suddenly increased by +30%, how long will it take for the tank temperature to achieve 99% of the final temperature change?
iii. If the inlet temperature is increased suddenly from 100 to 120 °C, how long will it take before the outlet temperature changes from 130 to 135 °C?

3. a. State the stability criterion using the given basic single-loop control system (Figure shown below). Describe how the root locations of the characteristic equation affect the stability of a linear control system, supported by the system's response behavior when roots are in: [5]



   i. In the right half of the complex plane
   ii. On the imaginary axis
   iii. In the left half of the complex plane.

   b. Explain theorems of the Routh test and how it determines the stability of a control system? For $\tau_1 = 1$, $\tau_2 = 1/2$, and $\tau_3 = 1/3$, determine the values of K_c for which the control system in Figure is stable. For the value of K_c for which the system is on the threshold of instability, determine the roots of the characteristic equation. [2+3]

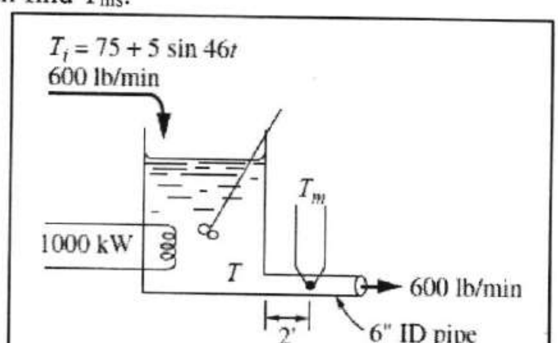


4. a. Explain the difference between air-to-close (AC) and air-to-open (AO) control valves, and describe a scenario in which an air-to-close valve would be preferred for safety reasons. What do you mean by control valve hysteresis? [5]

   b. Consider a stirred-tank heater with a capacity of 15 gal. Water is entering and leaving the tank at the constant rate of 600 lb/min. The heated water that leaves the tank enters a well-insulated section of 6-in-ID pipe. Two feet from the tank, a thermocouple is placed in this line for recording the tank temperature, as shown in Figure. The electrical heat input is held constant at 1000 kW. [5]

   Determine:

   i. If T_m is the thermocouple reading then find T_{ms}.
   ii. The time constant of the tank, τ_1
   iii. Transportation lag of the pipe, τ_2



5 Discuss the followings: [2+2+2+2+2]

   a. Single loop system by considering change in set point
   b. Root locus
   c. Second order system
   d. Gain and Phase Margin
   e. Zigler-Nichols controller settings