B.TECH/CHE/7TH SEM(L)/CHE 702/2021

INSTRUMENTATION & PROCESS CONTROL
(CHE 702)

Time Allotted : 3 hrs **Full Marks : 70**

The questions are of equal value.
The figures in the margin indicate full marks
Candidates are required to give answer in their own words as far as practicable.
All symbols are of usual significance.

Group – A
(Multiple Choice Type Questions)

1. Choose the correct alternative for the following (any ten): **10 × 1 = 10**

(i) The time constant of a mercury thermometer is given by
(a) $\frac{mC}{hA}$ (b) hA x mC (c) $\frac{hC}{mA}$ (d) hA

(ii) _____ is the largest range of values of a measured variable to which the instrument dose not respond.
(a) Drift (b) Sensitivity
(c) Dead zone (d) Fidelity.

(iii) Damped vibrator exhibits
(a) first-order dynamics (b) second order dynamics
(c) multicapacity system in series (d) none of these

(iv) Over damped system means damping coefficient is
(a) 1 (b) > 1 (c) < 1 (d) 0.

(v) The range of operation of a Mc.Leod gauge is
(a) 10 to 10^{-4} Torr (b) 1 to 10 atm
(c) 1 to 10^{-6} Torr (d) 2-600 MPa.

(vi) In underdamped second order system, decay ratio is equal to
(a) Overshoot (b) $(\text{overshoot})^{-1}$
(c) $(\text{Overshoot})^2$ (d) $(\text{overshoot})^{-2}$

(vii) A level transmitter senses the decrease in liquid level in a tank and feeds the output to a controller. A control valve is provided

at the liquid inlet. The type of controller and control valve used for the purpose will be
(a) direct-acting, air to close
(b) direct-acting, air to open
(c) reverse-acting, air to open
(d) reverse-acting, air to close.

(viii) An air to open valve provided at the inlet controls liquid level in a tank. When the liquid level is at set point, valve opening is 50%. An increase in outflow causes the valve opening to increase to 70%. What is the resulting offset if the controller proportional band is 50%?
(a) 10% below set point (b) 10% above set point
(c) no offset (d) 20% above setpoint

(ix) The type of controller most suitable for temperature control in a CSTR is
(a) P (b) PID (c) PI (d) on-off.

(x) Air to close type of control valve is most suitable for controlling
(a) Steam pressure in a reactor heating coil
(b) Flow rate of reactants into a reactor
(c) Flow of coolant to a distillation condenser
(d) Flow of effluent from a wastewater plant to a river.

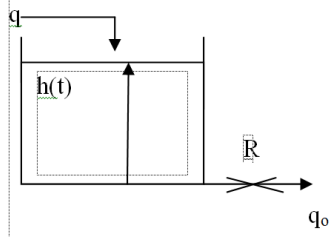
(xi) During temperature control of water in a steam-heated stirred tank heater, flowrate of steam is the
(a) controlled variable (b) measured variable
(c) disturbance variable (d) manipulated variable.

(xii) The response of a system with transportation lag τ produces amplitude ratio (AR) and phase angle(φ) as
(a) AR $= \frac{1}{\sqrt{\omega^2\tau^2+1}}$, $\varphi = -\omega\tau$,
(b) AR = 1, $\varphi = \tan^{-1}(-\omega\tau)$
(c) AR = 1, $\varphi = -\omega\tau$
(d) AR = $\sqrt{\omega^2\tau^2 + 1}$, $\varphi = \tan^{-1}(-\omega\tau)$

Group – B
(Short Answer Type Questions)

Answer any three of the following: **3 × 5 = 15**

2. The liquid-level system shown below has a cross-sectional area of 2 m^2. The outlet flow rate vs. head relationship of the valve is $q_o = 8\sqrt{h}$, where q_o is flow rate in m^3/min. and h (in meter) is the liquid level above the valve. Calculate the time constant for this system if the average operating level is 3 m.



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3. (a) What do you understand by "transportation lag"? Derive the transfer function.
   (b) Write down the characteristics of a manometric fluid.

3 + 2 = 5

4. A thermometer having a time constant of 0.08 min was placed in a temperature bath, and after the thermometer has come to equilibrium with the bath, the temperature of the bath was increased linearly with time at a rate of 1^0C/min. Find the response as a function of time. What is the difference between the indicated temperature and bath temperature after 0.2 min?

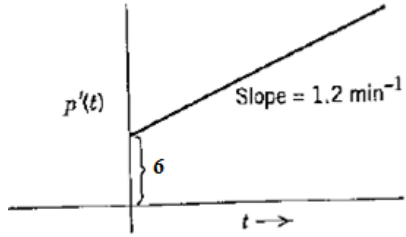
5

5. Explain the term reset windup. How can it be overcome? Explain the significance of reset time in a PI controller.

2 + 1 + 2 = 5

6. If the input Y_m to a PI controller changes stepwise ($Y_m(s) = 2/s$), and the controller output changes initially as in the figure shown, what are

the values of controller gain and integral time? Is the controller gain negative or positive?What is the significance of controller gain being negative?



3 + 1 + 1 = 5

Group – C
(Long Answer Type Questions)

Answer any three of the following: **3 × 15 = 45**

7. (a) State the mode of operation of a pyrometer.
   (b) A mercury thermometer having a time constant of 0.1 min is placed in a temperature bath at 50^0C and allowed to come to equilibrium with the bath. At time t=0, the temperature of the bath begins to vary sinusoidally about its average temperature of 50^0C with an amplitude of 2^0C. If the frequency of oscillation is $12/\pi$ cycles/min, obtain the ultimate response of the thermometer reading as a function of time. Also calculate the phase lag.
   (c) A step change of magnitude 2 is introduced into a system having the transfer function

$$\frac{Y(s)}{X(s)} = \frac{10}{s^2 + 1.6s + 4}$$

Determine
(i) percent overshoot
(ii) period of oscillation
(iii) maximum value of Y(t)
(iv) ultimate value of Y(t)

3 + (4 + 2) + 6 = 15

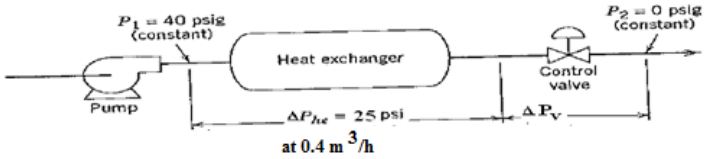
8. (a) Find the response when a unit impulse is applied to a critically damped second order system.
   (b) Derive the transfer function of two- tank interacting liquid-level system.
   (c) Two non-interacting liquid-level tanks are connected in series. The time constants are 0.8 min. and 0.5 min. respectively. The resistance in the second tank is l $m/m^3/min$. Obtain the dynamic response of the level in tank 2 if a unit-step change is made in the inlet flow rate to tank 1.

4 + 5 + 6 = 15

9. (a) The temperature of liquid in a stirred tank heater is controlled using a PI controller. If the temperature of the inlet liquid stream is suddenly increased by 5^0C, derive the expression for liquid temperature of outlet stream as a function of time and determine the offset. Represent the feedback control system by a block diagram.
   (b) The dynamic response of a stirred tank reactor is represented by
   $$\frac{C(s)}{C_{in}(s)} = \frac{4}{2s+1}$$
   where C is the exit concentration (mol/L) and C_{in} is the feed concentration (mol/L), which is initially 2 mol/L. Derive an expression for C(t) if a rectangular pulse of 4 mol/L is applied to the feed concentration for 2 min. What are the maximum and final values of exit substrate concentration?
   (c) Write the control algorithm of a PID controller in time domain and derive its transfer function in Laplace domain. Explain the significance of each term.

6 + 6 + 3 = 15

10. (a) A pump furnishes a constant head of 40 psig over the entire flowrate range of interest. The heat exchanger pressure drop (shown in figure) is assumed to be proportional to q^2.



If an equal percentage valve with valve characteristic given as f(l) = R $^{l-1}$ is used for controlling the flowrate, where l = stem lift, R =50, and the valve is fully open at 120% of the design flowrate, calculate the valve coefficient and write the design equation of the valve.

(b) Construct the Bode plot for the system specified below and evaluate the stability of the system:

$$G_p = \frac{4e^{-s}}{5s+1}$$

G_p = transfer function of the process, G_v = transfer function of the control valve = 2, G_m = transfer function of measuring element = 0.25 and G_c = transfer function of the P controller = K_c. Determine the crossover frequency, phase margin, gain margin, and K_c if K_c = 0.8 K_{cu}, where K_{cu} is the ultimate value of K_c. (Semilog graph paper required)

(c) Write the FOPDT model for the system specified: system gain K_p = 3, time constant τ_p = 3 min and time lag τ_D = 1.5. Using the Ziegler-Nichols rules, determine K_c and τ_I of the system if a PI controller is added to the system.

4 + 7 + 4 = 15

11. (a) Construct the root locus for a system with the following open loop transfer function

$$KG(s) = \frac{K(s+3)}{s(s+5)(s+6)(s^2+2s+2)}$$

Write the rules used for plotting the same. (Rectangular graph paper required)

(b) What is the significance of breakaway point?

(c) State the limitations of Routh test for determining the stability of a system.

12 + 2 + 1 = 15

12. Write short notes on *any three* of the following: **(3 × 5) = 15**

(i) Static and dynamic characteristics of an instrument
(ii) Working principle of a composition analyzer
(iii) Working principle of area and head flowmeter
(iv) Feedforward control
(v) Control valve and its applications.

Department & Section	Submission Link
CHE	Class Code fsvpeik
	Classroom Joining Link https://classroom.google.com/c/Mjk2ODgzMjM3Mjgx?cjc=fsvpeik
	Submission Link https://classroom.google.com/c/Mjk2ODgzMjM3Mjgx/a/NDYyMjY3NjYwNzE0/details