PROCESS CONTROL AND INSTRUMENTATION (CHEN 3201)

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

Figures out of the right margin indicate full marks.

Candidates are required to answer Group A and any 5 (five) from Group B to E, taking at least one from each group.

Candidates are required to give answer in their own words as far as practicable.

Group – A (Multiple Choice Type Questions)

1. Choose the correct alternative for the following: **10 × 1 = 10**

(i) Transfer function for transportation lag is
(a) $e^{\tau s}$ (b) $e^{-\tau s}$
(c) $\frac{1}{\tau s+1}$ (d) $e^{\tau s+1}$

(ii) Response of a system to a sinusoidal input is __________ response.
(a) Impulse (b) pulse
(c) step (d) frequency

(iii) For two liquid-level tanks in series, the damping coefficient can never be
(a) more than 1 (b) equal to 1
(c) less than 1 (d) zero

(iv) In second order under damped system,
(a) decay ratio = overshoot (b) decay ratio = $(\text{overshoot})^2$
(c) decay ratio = $(\text{overshoot})^{0.5}$ (d) none of these.

(v) Time constant of a mercury-in-glass thermometer is equal to
(a) $\frac{mC}{hA}$ (b) $\frac{hC}{mA}$
(c) (mC/A) (d) $\frac{hC}{m}$

(vi) A system is unstable if
(a) Poles of the system have positive real parts
(b) Poles of the system have negative real parts
(c) Poles of the system are complex
(d) Poles of the system are imaginary.

(vii) In Cohen-Coon tuning, the process reaction curve is approximated by
(a) Second order plus dead time model (b) Dead time model
(c) First order plus dead time model (d) First order model

(viii) In FOPDT model, the direct synthesis method of controller design yields
(a) A PI controller with controller gain inversely proportional to model gain and desired closed loop time constant
(b) A PI controller with controller gain directly proportional to model gain and desired closed loop time constant
(c) A P controller with controller gain inversely proportional to model gain
(d) A PID controller with controller gain inversely proportional to model gain and desired closed loop time constant

(ix) The basic principle of hot wire anemometer is
(a) Measurement of gas flowrate as a function of change of wire resistance due to heat transfer from wire to gas
(b) Measurement of gas flowrate as a function of expansion of wire due to transfer of heat from gas to wire
(c) Measurement of gas flowrate as a function of change of wire resistance due to heat transfer from gas to wire
(d) Measurement of gas flowrate as a function of wire temperature

(x) The conductor used for resistive method of liquid level measurement is
(a) Mercury (b) Copper sulphate
(c) Potassium chloride (d) Water

Group – B

2. (a) A mercury thermometer having a time constant 0.12 minute is placed in a temperature bath maintained at 40^0C 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 40^0C with an amplitude of 1^0C. The frequency of oscillation is (8/π) cycles/min.
(i) Find the ultimate response of the thermometer as a function of time.
(ii) Also find out amplitude ratio and phase lag in min.

(b) (i) Obtain the transfer function of a pure capacitive process.
(ii) Why is this system named as pure integrator?

(4 + 2) + (4 + 2) = 12

3. (a) For a tank of cross-sectional area 100 cm^2 and inlet flowrate q_i (in cm^3/s), the outlet flow rate, q_o(in cm^3/s) is related to the liquid height h (in cm) as $q_o=3\sqrt{h}$. Obtain the transfer function of the process around the steady-state point , q_{is}=18 cm^3/s and h_s =36 cm.

(b) Explain with sketch the feedback and feed forward temperature control for a stirred tank heater system.

(c) A stream of solution containing dissolved salt flows at a constant volumetric flow rate 4 lit/min into stirred a tank of constant holdup volume 16 litre. Obtain the response in **y** (salt concentration in outlet stream) as a function of time if there is a change in input salt concentration **x** by a step function of 0.4 unit.

5 + 3 + 4 = 12

Group – C

4. (a) Obtain the response in outlet flowrate from 2nd tank as a function of time when an impulse of 0.6 unit is applied in inlet flowrate of the first tank of the two tank non-interacting system, each having identical time constant of 0.5 unit. What is the damping factor?

(b) A step change of magnitude 3 is introduced in a system having following transfer function

$$\frac{Y(s)}{X(s)} = \frac{10}{(2s^2 + 0.5s + 0.5)}$$

Determine the overshoot, period of oscillation and maximum value of the response.

(5 + 1) + (2 + 2 + 2) = 12

5. (a) Construct the root locus diagram of the following characteristic equation stating the different rules used to make the plot

$$1 + \frac{K}{s(s+3)(s^2+2s+2)} = 0$$

Locate at least one trial point in the plot and determine the value of K for that point (rectangular graph paper required)

(b) Using Routh stability criterion, determine the stability of the system with the following characteristic equation

$$1 + \frac{K_c}{(s+1)\left(\frac{s}{2}+1\right)\left(\frac{s}{3}+1\right)} = 0$$

State the different theorems for Routh test

8 + 4 = 12

Group – D

6. (a) Construct the Bode plot(amplitude ratio and phase angle plots) of the following open loop transfer function

$$G_{OL}(s) = \frac{2K_c e^{-0.3s}}{4s+1}$$

Compute the gain margin and phase margin. With the help of this plot, determine the value of the proportional gain K_c using Ziegler Nichols controller tuning. If a PI controller is used, what would be the controller settings? (log-log and rectangular graph papers required).

Ziegler-Nichols controller settings

Type of control	$G_c(S)$	K_c	τ_I	τ_D
Proportional	K_c	$0.5K_u$		
Proportional-integral (PI)	$K_c\left(1+\frac{1}{\tau_I s}\right)$	$0.45K_u$	$\frac{P_u}{1.2}$	
Proportional-integral-derivative (PID)	$K_c\left(1+\frac{1}{\tau_I s}+\tau_D s\right)$	$0.6K_u$	$\frac{P_u}{2}$	$\frac{P_u}{8}$

(b) Obtain the expressions for offset in closed loop responses of a first order system if unit step changes in load and setpoint are applied separately to the system in the presence of a proportional controller. Sketch the closed loop responses for both cases. What is integral windup?

8 + (2 + 2) = 12

7. (a) Explain the basic principle of ratio control with diagrams. State the industrial applications of ratio control.

(b) What is the objective of adaptive control? Discuss gain scheduling adaptive control and compare it with feedback control with the aid of block diagrams. Give examples of industrial applications of auctioneering control and inferential control.

(3 + 2) + (2 + 3 + 2) = 12

Group – E

8. (a) Explain with diagrams the working principles of Resistance temperature detectors. Describe the working principle of diaphragm pressure gauges.

(b) Explain the terms: (i) Reproducibility (ii) Dead band (iii) Linearity (iv) Hysteresis

(4 + 4) + 4 = 12

9. (a) Discuss the different control valve characteristics. Why is equal percentage valve named so?

(b) Enumerate the different components of a piping and instrumentation diagram. Represent symbolically centrifugal pump, positive displacement pump and pneumatic operated fail open valve. Draw the process flow diagram of hydrodealkylation of toluene to benzene explaining the different symbols

(2 + 1) + (2 + 2 + 5) = 12

Department & Section	Submission Link
CHE (Regular & Backlog)	https://classroom.google.com/c/Mjk2ODgzMjM3Mjgx/a/MzY0NTU4MzE4ODE2/details