PROCESS DYNAMICS, INSTRUMENTATION AND CONTROL (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) For measuring a very low temperature of around - 225°C, you will use a
(a) toluene thermometer (b) resistance thermometer
(c) thermocouple (d) bimetallic thermometer.

(ii) An example of zero-suppressed type range is
(a) 0°C - 100°C (b) -25°C - 250°C
(d) -30°C - -10°C (d) 20°C - 150°C.

(iii) Laplace transform of impulse input of magnitude A is
(a) 0 (b) 1 (c) A (d) 1/A.

(iv) For a second order system, two complex conjugate poles are obtained in case of
(a) critically damped response (b) underdamped response
(c) overdamped response (d) all the above responses.

(v) In under damped second order system, decay ratio is equal to
(a) overshoot (b) $(\text{overshoot})^{-1}$
(c) $(\text{overshoot})^{2}$ (d) $(\text{overshoot})^{-2}$.

(vi) If A is cross sectional area, and R is linear resistance in case of a liquid-level tank, the time constant is given by
(a) A.R (b) A/R (c) A^2R (d) R^2A.

(vii) The frequency response of a first order system, has a phase shift with lower and upper bounds given by
(a) $-\infty, \pi/2$ (b) $-\pi/2, \pi/2$
(c) $-\pi/2, 0$ (d) $0, \pi/2$.

(viii) A proportional controller is used for on-off control if the gain K_C is made
(a) very low (b) equal to zero
(c) very high (d) equal to 1.

(ix) All branches of root locus start at
(a) Open loop zeroes (b) Open loop poles
(c) Origin (0, 0) (d) infinity.

(x) The frequency for which the phase lag in a frequency response is 180° is called
(a) corner frequency (b) natural frequency
(c) crossover frequency (d) resonant frequency.

Group – B

2. (a) Define reliability of a measurement system. Distinguish between precision and accuracy.

(b) A milliammeter has a range of 0 – 30 mA and its accuracy is ± 0.2% of full scale value. If the ammeter is used to measure current of 15 mA, find the output reading.

(c) What is direct calibration? Give an example.

(1 + 3) + 4 + 4 = 12

3. (a) A thermometer has a first order response with time constant of 1 second. It is given a step input of 60°C from 0°C. Calculate the temperature indicated after 0.8 s of application of the step input.

(b) What are the sources of static error in an inclined leg manometer?

(c) "A disadvantage of the Float and Tape type level gauge is that remote indication cannot be obtained". How can you overcome this disadvantage for this type of level gauge? Explain with a diagram.

5 + 3 + 4 = 12

Group – C

4. (a) 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.

(b) The unit impulse response of a first order process is given by $2e^{-0.5t}$. Calculate the gain and time constant of the process.

(c) The liquid-level system shown in Fig.1 has 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.

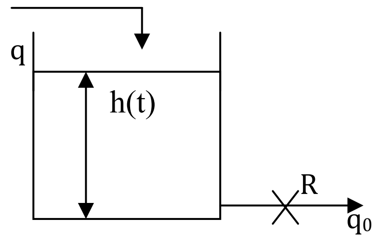

Fig.1

6 + 2 + 4 = 12

5. (a) Two non-interacting liquid-level tanks are connected in series. The time constants are 1.0 min and 0.7 min. respectively. The resistance in the second tank is 1 m/(m³/min). Obtain the dynamic response of the level in tank 2 if a step change of magnitude 0.1 m³/min is made in the inlet flow rate to tank 1.

(b) A unit gain 2nd order under damped process has a period of oscillation 1 second and decay ratio of 0.25. Find the transfer function of the process.

(c) If $y(s) = \frac{1}{2s^2 + 3s + 1}$, then obtain the inverse Laplace Transform, y(t).

7 + 3 + 2 = 12

Group – D

6. (a) Obtain an expression of offset for set point change in case of heated stirred tank fitted with a proportional controller.

(b) Derive an expression for the transfer function of a P-I-D controller

(c) What do you understand by characteristic curves of control valve? Mention the equation used for sizing of control valve.

4 + 4 + 4 = 12

7. A PD controller is used in a control system having a first-order process and a measurement lag as shown in figure 2.

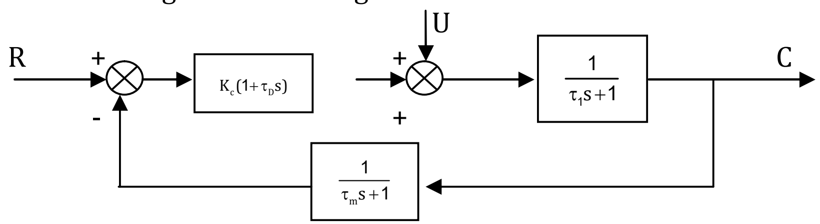

Fig.2

(i) Obtain C(s)/R(s). Find expressions for damping coefficient ξ and time constant τ for the closed-loop response.

(ii) If τ_1 = 1 min, τ_m = 10 sec, find K_c so that ξ = 0.7, for the two cases: (1) $\tau_D = 0$ (2) τ_D = 3 sec

(iii) Compare the offset and period realized for both cases if a unit step change in set point is introduced. State the advantage or disadvantage of adding derivative mode.

12

Group – E

8. (a) How can you apply the Routh test to test the stability of a system containing a transportation lag?
The characteristic equation for a 3rd order control system is given by:

$$1 + K_c/(s+1)[(s/2) + 1)][(s/3) + 1] = 0$$

Determine the values of the controller gain for which the control system is stable.

(b) The open loop transfer function for a feedback system is given by

$$G(s) = k/s(s + 1)(s + 2)$$

Sketch the root locus plot. Find the breakaway points and the maximum gain beyond which the system becomes unstable.

(1 + 4) + 7 = 12

9. Consider a feedback control system with a first-order process $\left[G_P(S) = \frac{2}{10s+1}\right]$, a proportional controller, and a first-order measuring element $\left[G_P(S) = \frac{1}{5s+1}\right]$. The remaining elements are all very fast (i.e., with no dynamics) and unity-gain.

(i) In order to make an exact stability analysis to find the range of values for controller gain K_c what method would you choose — Routh stability analysis or Frequency Response? Explain why and use the correct method to find $K_{C_{max}}$.

(ii) Now, a dead time of 1 second (that was neglected in part (i) above) present in the above loop is to be taken into account. Which of Routh stability analysis and Frequency Response would now provide an exact stability analysis to find the limit on K_c? Why? Perform the analysis using the correct technique.

(6 + 6) = 12