 Set No.1

III B.Tech. II Semester Regular Examinations, April/May -2005
PROCESS DYNAMICS AND CONTROL
(Chemical Engineering)

Time: 3 hours **Max Marks: 80**

Answer any FIVE Questions
All Questions carry equal marks
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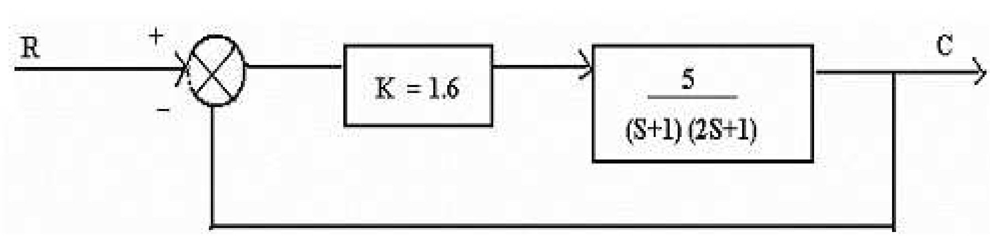
1. (a) Derive an expression for the dynamic response of a general first order system for step change in input.
   (b) A mercury thermometer having a first order dynamics with a time constant of 60 sec. is placed in a temperature bath at 35^0 C. After the thermostat reaches its steady state, it is suddenly placed in a bath at 40^0 C at time t = 0. Calculate the variation of temperature with time for a period of 60 seconds considering an incremental time of 10 seconds.
2. (a) Define and explain transportation lag.
   (b) Develop transfer function for transportation lag.
3. Discuss the working principle & mechanism of pneumatic PID controller with the help of a neat schematic diagram.
4. The set point of the control system shown below is given a step change of 0.1 unit. Determine:
   (a) The maximum value of C and the time at which it occurs.
   (b) The offset.
   (c) The period of oscillation - Draw the sketch of c(t) as a function of time.



5. (a) Define the stability of a linear system and explain the Routh stability criteria
   (b) Discuss the effect of K_C, T_I and T_D on the closed response of a process controller with PID
6. (a) Explain the concept of Root Locus
   (b) Explain the procedure of plotting root locus diagram. State also the rules.

7. A process control system is to contain one first order lag with 25 sec, another with a lag of 10 sec, a delay of 8 sec and a single proportional controller with unit gain. Construct a Bode diagram for the open loop and find the open-loop steady state gain that will give a phase margin of 30. What gain margin will this give?

8. Discuss the Cohen and Coon rules of controller tuning in detail.

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1. (a) Express the general form of first order transfer function. Write the expressions for the response in Laplace and time domain for step change in input.
   (b) Determine the transfer functions of the system described by the following equations, $-\frac{dx}{dt} = a_1(x - y)$,$-\frac{dy}{dt} = a_2(y - z) - a_3(x - y)$ subject to initial conditions X(0)=0 and Y(0)=0. x(t) and y(t) are outputs and z(t) is the input. Derive the transfer function relating
      i. y and z
      ii. x and z.
2. (a) Show the block diagram representation of several non interacting first order systems in series. How do you express the overall transfer function from individual transfer functions of several first order systems in series?
   (b) A step change of magnitude 3 is introduced into the transfer function $\frac{Y(s)}{X(s)} = \frac{10}{[2s^2+0.3s+0.5]}$ Determine the overshoot and frequency of oscillation
3. (a) A unit step change is given to a PI controller. If the proportional sensitivity or gain K_C is 4, the integral time τ_1 is 2, obtain the response of the PI controller.
   (b) Differentiate negative feed back and positive feed back.
4. (a) Develop the block diagram of a generalized feed back control system with one disturbance, incorporating in each block the appropriate transfer function and on each stream the appropriate variable.
   (b) Develop the closed loop responses for set point and load changes.
5. Given the characteristic equation $s^4+3s^3+5s^2+4s+2 = 0$, determine the stability by Routh criterion.
6. Plot the Root locus of the transfer function given as $\frac{Y(S)}{X(S)} = \frac{6}{3\,S^3+4\,S^2+5S+1}$ Discuss the stability of the system.
7. Construct the Bode diagram of a first-order system with dead time having a transfer function. $G(s) = \frac{K_p e^{-t_d s}}{\tau_p s+1}$
8. (a) Explain ratio control in detail with a neat schematic diagram.
   (b) Quote some commonly encountered examples from chemical industry where ratio control can be used.

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1. (a) An isothermal, constant hold up, constant throughput CSTR with a first order irreversible reaction is described by,
$\frac{dC_A}{dt} + \left(\frac{F}{V} + k\right) C_A = \frac{F}{V} C_{Ao}$
where F is the stream flow rate, V is the volume of reactor, and k is the reaction rate constant. Derive an expression for the solution a of reactant concentration C_A for a ramp change in feed concentration , C_{A0}.
   (b) The transfer function model of a system is given by $G(s) = \frac{10}{0.2s+1} - \frac{5}{0.3s+1}$ Plot the response to a sinusoidal input, sin 2 t.

2. Assuming the flow in the manometer to be laminar and the steady-state friction for drag force in laminar flow to apply at each instant, determine a transfer function between the applied pressure P1 and the manometer reading h. It will simplify the calculations if, for inertial terms, the velocity profile is assumed to be flat. From transfer function, written in the standard second order form, list
   (a) the steady state gain,
   (b) τ and
   (c) ζ

   Comment on these parameters as they are related to the physical nature of the problem.

3. (a) In a PID controller the error is increased linearly at the rate of $5^0 C/min$. The proportional sensitivity of the PID controller is 4, the reset rate is 1 and the derivative time is 0.5. Obtain the response equation of the controller.
   (b) Write about servo problem versus regulator problem.

4. For a first order processes with proportional controller derive response equations for set point change as well as load change.

5. (a) Discuss the theorems of the Routh test
   (b) For characteristic equation $s^4 + 6s^3 + 11s^2 + 36s + 120 = 0$, determine the stability using Routh Criterion.

6. Sketch the root loci for the control system having the characteristics equation $1 + \frac{K}{(s+1)(s+2)(s+4)} = 0$ Locate quantitatively all the poles, zeros, asymptotes, break away point and imaginary axis cutting points.

7. For the transfer function shown below, sketch the gain versus frequency portion of the asymptotic plot of the Bode diagram. Determine the actual value of gain and phase angle at $\omega = 1$ Determine the phase angle as $\omega \to \infty$
   $G(s) = \frac{2(0.1s+1)}{s^2(10s+1)}$
   Indicate very clearly the slopes of the asymptotic bode diagram of G(s).

8. Explain linear, equal percentage and square root characteristics of control valves.

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1. (a) An isothermal CSTR irreversible reaction is described by $\frac{dC_A}{dt} + \left(\frac{1}{\tau} + k\right) C_A = \frac{1}{\tau} C_{Ao}$ where k and τ are constants. The initial condition is C_{A0} (0)=0. Derive an expression for the solution a of reactant concentration CA for a step change in feed concentration , C_{A0}.

   (b) The transfer function of a system is given by $\frac{X(s)}{F(s)} = \frac{1}{(s-1)(s-2)}$ where X(s) is the output and F(s) is the input. Obtain an expression for x(t) for a unit step change in input.

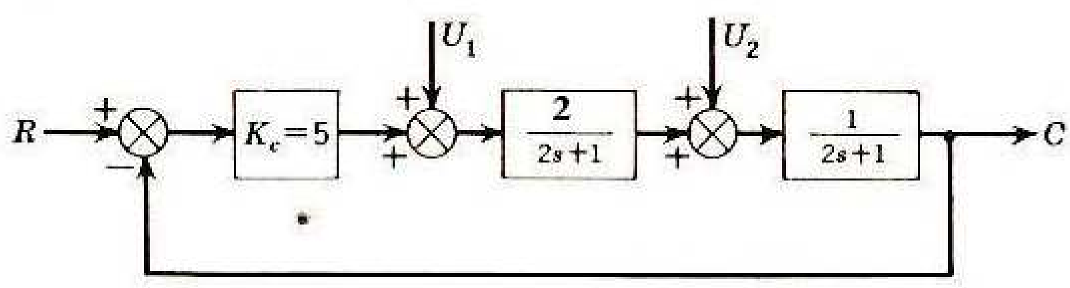
2. What is meant by second order transfer function? Derive the second order transfer function in case of a damped oscillator. Give expressions for the time constant and damping coefficient.

3. Explain in detail with a block diagram, working mechanism of a proportional pneumatic controller.

4. The location of the load change in a control loop may affect the system response. In the block diagram shown in the figure given below, a unit – step change in load enters at either location 1 or location 2

   (a) What is the offset when the load enters at location 1 and when it enters at location 2 ?

   (b) Sketch the transient response to a step change in U_1 and to a step change in U_2.



5. (a) A system has the characteristic equation, $S^5 + 7S^4 + 18S^3 + 23S^2 + 17S + 6 = 0$ By using the Routh criterion determine whether or not the system is stable.

   (b) Explain servo and regulatory control problems with an example.

6. Sketch the root locus for the following equation.
   $1 + \frac{k}{(s+1)(2s+1)} = 0$
   on your sketch you should locate quantitative all poles, zeros, and asymptotes. In addition show the parameter that is being varied along the locus and direct in which the loci travel as this parameter is increased.

7. For the system given below, determine accurately the phase angle in degree between Y(t) and X(t) for $\omega = 0.5$. Determine the lag between the input wave and the output wave $X = 2\sin\omega t \rightarrow \boxed{(3/9s^2 + 0.5s + 1)} \rightarrow Y$

8. Write in detail on valve sizing and selection.

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