III B.Tech II Semester Examinations,APRIL 2011
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. For the following liquid level system shown in figure 1, derive a transfer function from the first principles relating the liquid level (H) of the tank to inlet flow (Q). [16]

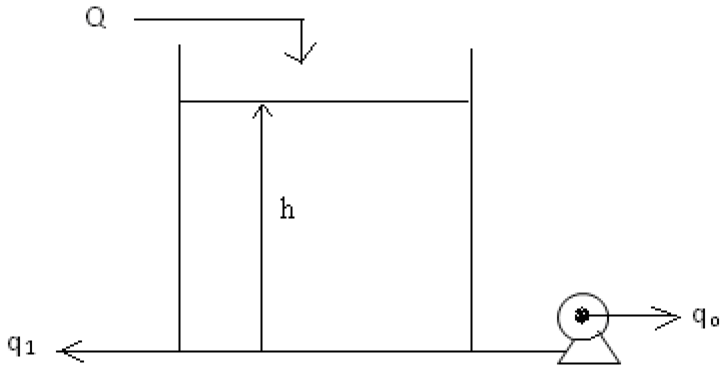


Figure 1:

2. Discuss the strategies in implementing the following:
   (a) Cascade control
   (b) Feed forward control. [8+8]

3. (a) Explain the response of a PD controller to a linear input in error.
   (b) Giving example, explain the terms proportions gain, proportional band, and the relation between them. [8+8]

4. A process has the third order transfer function (time constant in minutes)
   $G_p(s) = \frac{2}{(0.5s+1)^3}$
   Also $G_v = 0.1$ and $G_m = 10$. For a proportional controller, evaluate the stability of the closed loop control system, using the Bode stability criterion and three values of $K_c = 1$, 4 and 20. This process has an open loop transfer function $G_{OL} = G_c G_v G_p G_m$. [16]

5. (a) Explain the plotting of root locus diagrams stating the rules to be followed.
   (b) Plot the root locus pattern of a system whose characteristic equation is :
   $1 + \frac{K}{s(s+2)(s+4)}$. [8+8]

6. (a) Explain why two interacting first order systems have more sluggish response than two equivalent but non-interacting systems.

   (b) Sketch qualitatively, the response of systems with the following transfer function
   $G(s) = \frac{s+1}{(s+2)(s+3)}$. [8+8]

7. The following block diagram figure 2 corresponds to a control system with two loops. Reduce the block diagram to a simple one, such as that shown in figure 3, by identifying the approximate transfer functions $G_1, G_2 and G_3$. [16]

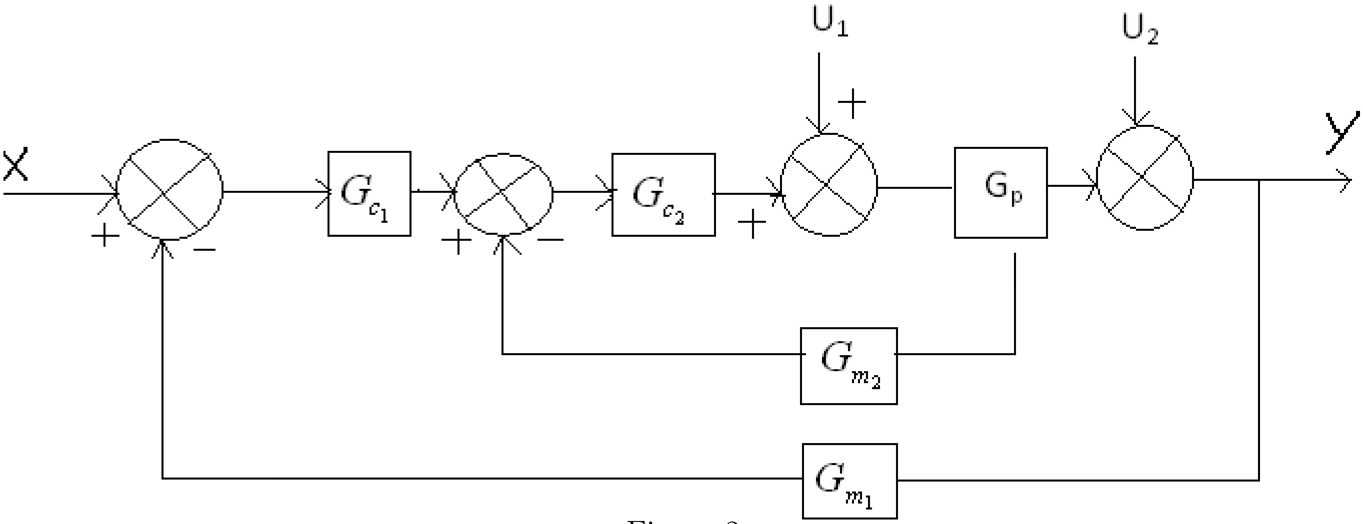


Figure 2:

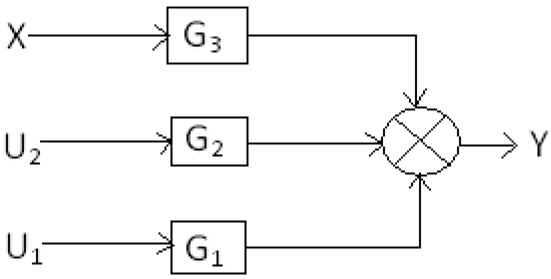
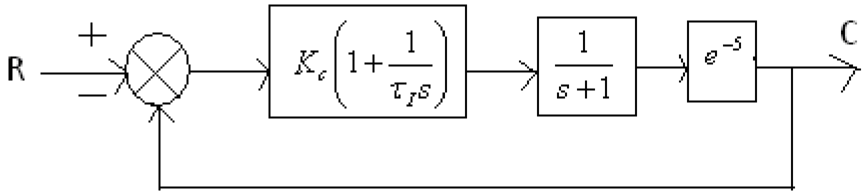


Figure 3:

8. (a) For the controller system shown in the figure 4 below, determine controller settings using Z-N method.

   (b) Explain the characteristics of control valves in detail. [10+6]



Code No: 07A60804 **R07** **Set No. 4**

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1. A transfer function of a first-order process is given by
$$\frac{Y(s)}{X(s)} = G(s) = \frac{K}{\tau s+1}$$
   (a) Find the ramp response to a ramp function with slope A.
   (b) Find the response to sinusoidal input A$\sin\omega$t Represent the results graphically. [16]

2. (a) Explain by means of a process example the working of a typical cascade control system.
   (b) Explain why feed forward control gives approximate, through rapid, corrective action, while feed back control gives long term but accurate corrective action. [8+8]

3. For the control system in the figure 5:
   (a) Determine the value of K above which the system is unstable.
   (b) Determine the value of K for which two of the roots are on the imaginary axis, and determine the values of these imaginary roots and the remaining two roots. [8+8]

4. A control system shown below figure 6 contains a three-mode controller.
   (a) For a closed loop, develop expressions for the natural period of oscillation ? and the damping factor in terms of the parameters K, τ_D, τ_I and τ_1, when τ_D= τ_I =1 and τ_I = 2.
   (b) Calculate ς for K = 2.
   (c) Find the response, for a unit step change in load for K =2. [8+4+4]

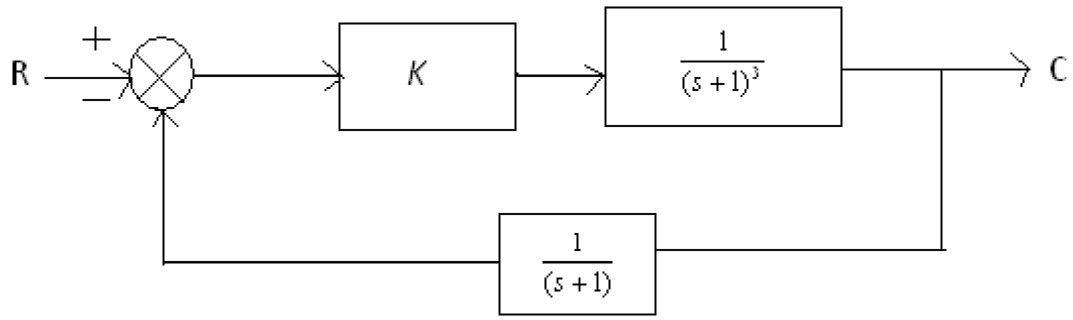

Figure 5:

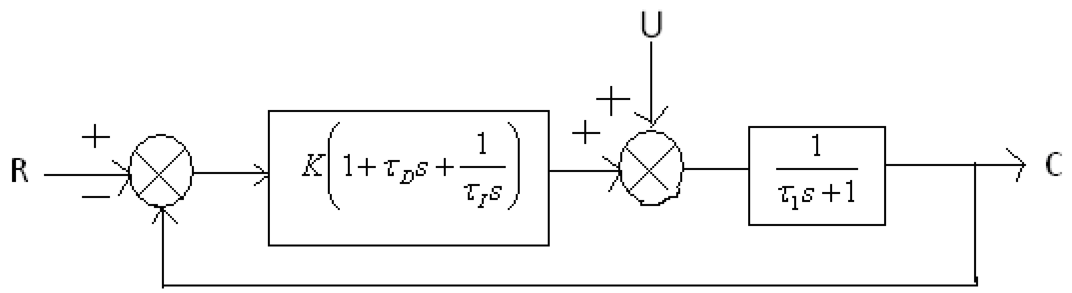

Figure 6:

5. Explain Pneumatic control valves are to be specified for the applications listed below. Explain whether an air to open or air to close should be specified for the following manipulated variables.

   (a) Steam pressure in a reactor heating coil.

   (b) Flow rate of reactants into a polymerization tank.

   (c) Flow of effluent from a waste water treatment holding tank into a river.

   (d) Flow of cooling water to a distillation condenser. [16]

6. (a) Define tuning and explain Cohen-coon method of controller tuning.

   (b) Write short notes on:

      i. Inherent valve characteristics.

      ii. Control valve hysteresis. [10+6]

7. A shell and tube heat exchanger has the following dynamics:

$$\frac{T_{fe}(s)}{Q_f(s)} = \frac{\exp(-0.05s)}{4s+1}$$

$$\frac{T_{fe}(s)}{Q_h(s)} = \frac{0.5\exp(-0.05s)}{(4s+1)(s+1)}$$

Where T_{fe} is the temperature of the exit process fluid, Q_f and Q_h ar the flow rates of process fluid and the heating medium respectively. It is proposed to control the exchanger by a proportional controller by measuring T_{fe} and manipulating Q_h. All other lags in the loop are negligible. Determine the value of the proportional gain, such that the system has a phase margin of 30^0. [16]

8. A general second order system is described by the ODE $\tau_p^2 \frac{d^2x}{dt^2} + 2\tau_p\zeta\frac{dx}{dt} + x = K_p$ m(t).
   If j>1, show that the system transfer function has two first order lags with time constants $\tau_{p_1} and \tau_{p_2}$. Express these time constants in terms of $\tau_p and \zeta$.

   [16]

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Code No: 07A60804 **R07** **Set No. 1**

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1. What do you understand by process identification? Explain the methods used for this purpose. [16]

2. (a) Explain the Bode stability criterion.
   (b) Using the Bode stability criterion, find the range of Kc values that stabilise the unstable process $G_p(s) = \frac{1}{s-5}$. [6+10]

3. A feed back control system has the open-loop transfer function
   $G_{OL} = \frac{4K_c}{(s+1)(s+2)(s+3)}$
   Plot the root locus diagram for $0 \le K_c \le 20$. Show all the necessary calculations to plot the root locus diagram. [16]

4. (a) Examine the effect that various values of the gain K_m of a measuring device will have on the closed loop response of a process with the following transfer function: $G_p(s) = \frac{1}{(s+1)(2s+1)}$. Assume that $G_m = K_m$ and the controller is proportional with $K_c = 1$.
   (b) Find the transfer function Y(s)/X(s) of the system given below figure 7:

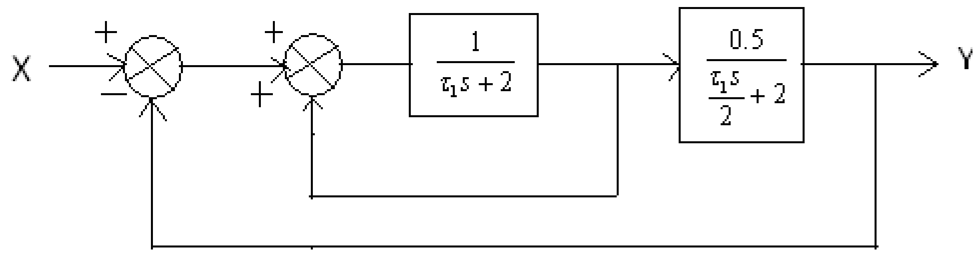

Figure 7:

[8+8]

5. Three identical tanks are operated in series in a non-interacting fashion as shown in the figure 8. For each tank, R =1, $\tau = 1$. If the deviation in flow rate to the first tank is an impulse function of magnitude 2, determine:
   (a) An expression for H(s) where H is the deviation in level in the third tank.
   (b) Sketch the response H(t).
   (c) Obtain an expression for H(t). [7+3+6]

6. (a) Derive the linear response equation for a first order system.

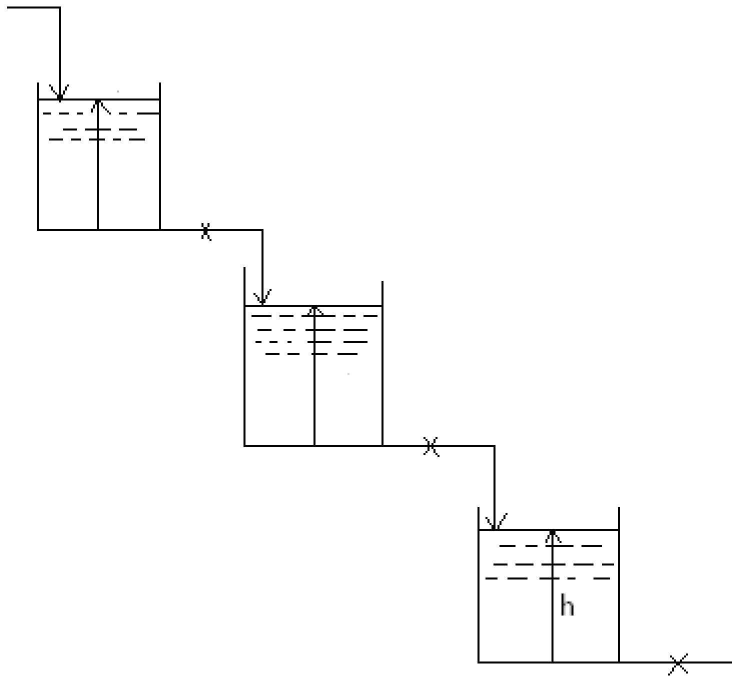

Figure 8:

(b) Sketch the time function corresponding to the transform
$F(s) = \frac{1}{s}\left[1 + \exp(-s) - \exp(-2s) - \exp(-3s)\right]$. [8+8]

7. Compare by plotting response of cascade control with that of conventional control for the overall process, which consists of

Primary process: $G_{PI}(s) = \frac{1}{(0.5s+1)(s+1)}$ *and* Secondary process $G_{PII}(s) = \frac{1}{(0.1s+1)}$

Assume all controllers of proportional type with gain K_{cI} = K_c (conventional) = 2.0 and K_{cII} = 5.0
Consider a unit load change entering in secondary process [16]

8. An ideal PD controller had the transfer function
$\frac{P}{\varepsilon} = K_c(\tau_D s + 1)$
An actual PD controller had the transfer function
$\frac{P}{\varepsilon} = K_c\frac{(\tau_D s+1)}{(\tau_D/\beta)s+1}$
Where β is a large constant in an industrial controller. If a unit-step change in error is introduced into a controller having the second transfer function, show that
$P(t) = K_c(1 + A\exp(-\beta t/\tau_D)$
Where A is a function of β which you are to determine. For $\beta = 5$ and $K_c = 0.5$, plot P(t) versus t/τ_D. As $\beta \rightarrow \infty$, show that the unit-step response approaches that for the ideal controller. [16]

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1. For the control system show below figure 9:

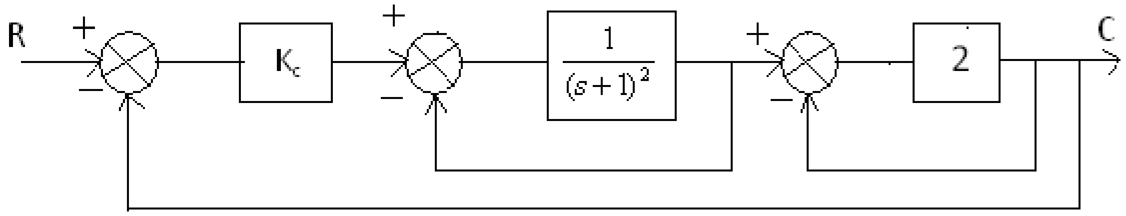

Figure 9:

   (a) Derive a transfer function C(s)/R(s)
   (b) Determine the value of K_c for which the system is critically damped. [8+8]

2. (a) Draw and explain the schematic diagram of a control system for a process of your choice.
   (b) Explain the terms reset rate and rate control. [10+6]

3. What are the various controller tuning methods you know? Explain how they are used with equations of figures, briefly. [16]

4. (a) Discuss the similarities and differences of ratio control to feed-forward control with necessary block diagrams.
   (b) Explain the nature of inputs that must be specified in implementing the IMC method of control. [10+6]

5. Consider the conical water tank system shown below figure 10. The flow through the valve is related to the head H by $Q = 0.005\sqrt{H}$, where Q is the flow rate measured in m^3/sec and H is in meters. Suppose that head is 2 m at t=0, what will be the head at t= 60 sec? [16]

6. Plot the asymptotic Bode diagram for the PID controller:
   $G(s) = K_c\left(1 + \tau_D s + \frac{1}{\tau_I s}\right)$ where K_c=10; $\tau_D = 1$; τ_I =100.
   Label corner frequencies and give slopes of asymptotes. [16]

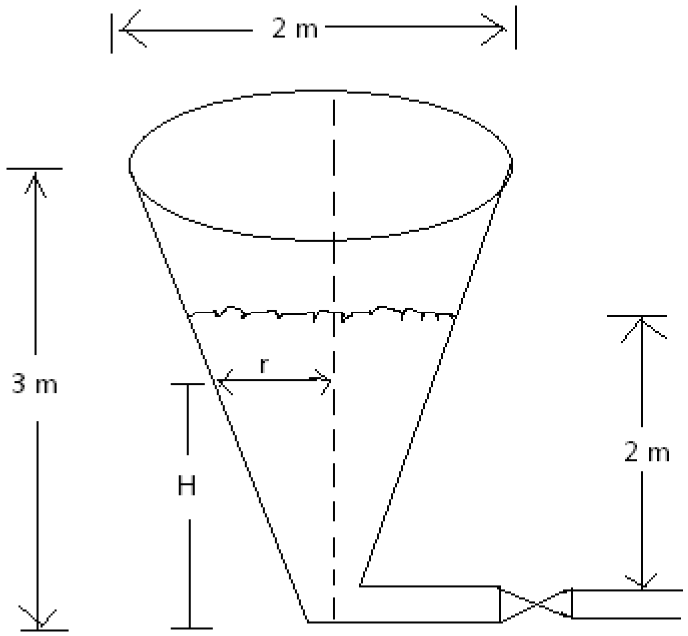

Figure 10:

7. Draw the root-locus figure 11 for the following control system.
   (a) Determine the value of Kc needed to obtain a root of the characteristic equation of the closed-loop response which has an imaginary part 0.75.
   (b) Using the value of Kc found in part (a), determine all the other roots of the characteristic equation from the root-locus diagram. [8+8]

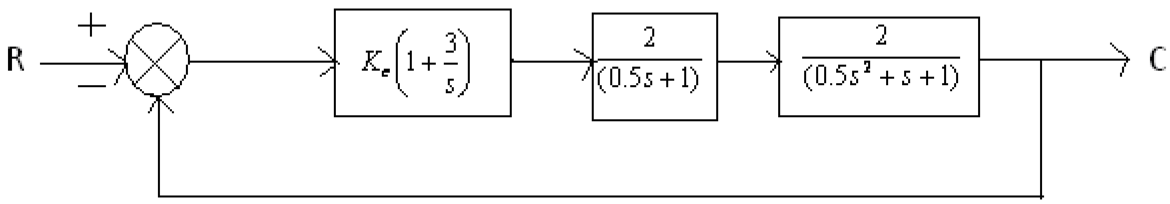

Figure 11:

8. A liquid system is shown in below figure 12:
   Derive a transfer function $H_2(s)/W_i(s)$. Assume that resistance to flow W_1(t) is constant.

   [16]

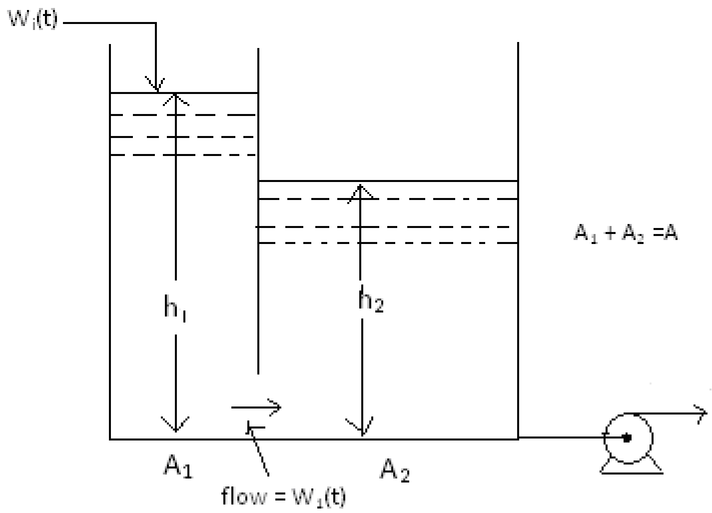

Figure 12:

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