Dr Puneet Sinha

24/11/2023

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राष्ट्रीय प्रौद्योगिकी संस्थान, हमीरपुर
National Institute of Technology, Hamirpur

B. Tech. (Chemical Engineering) - 5th Semester

Final Term Exam (24th November 2023)

CH-314 Process Dynamics and Control

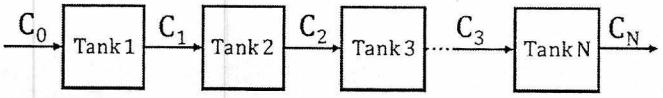
Duration: 3 Hours **Max. Marks: 50**

Ques: 1 (a) A step change of magnitude 5 is introduced into a system having transfer function

$$\frac{Y(s)}{X(s)} = \frac{30}{90000S^2 + 240S + 1}$$

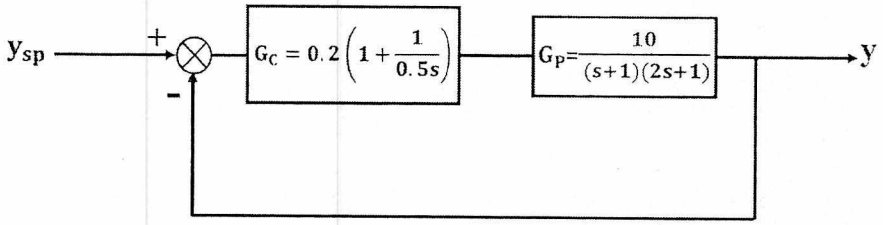
Determine Rise Time (t_r), Peak time (t_p) and Maximum value of y(t). **3 Marks**

(b) N storage tanks each of volume V are arranged so that water is fed into first tank, second tank and so on. Each tank initially contains pure water and is equipped with a perfect stirrer. At zero time, a stream of concentration C_0 is fed into the first tank with flow rate, q. Find the concentration for the n^{th} tank as a function of time. **4 Marks**

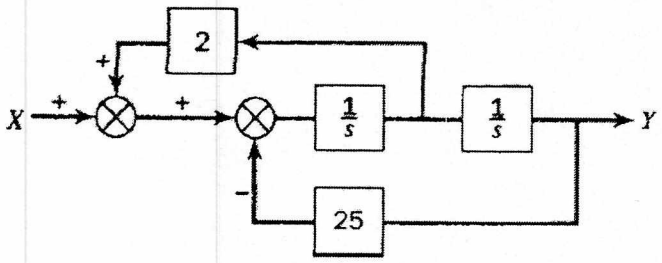


(c) Make Nyquist plot of a second order system. **1 Mark**

Ques: 2 (a) A unit step change is given at the input to the system given in the block diagram. Find out the offset. **2 Marks**

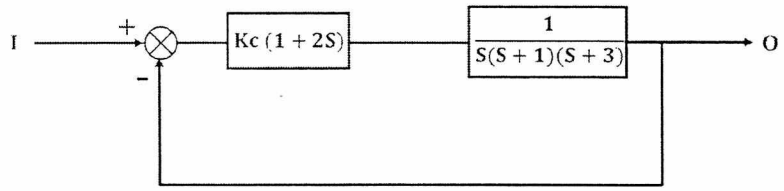


(b) Reduce block diagram in the figure below to find Y/X. **5 Marks**



Ques: 3 (a) How can the temperature of a cool fluid using hot fluid be precisely controlled using a double-pipe heat exchanger? Propose a block diagram to achieve this goal. Explain the significance of each component in the system. **3 Marks**

(b) Consider a feedback control system with the following block diagram



Sketch the root locus diagram for the closed loop system as K_C (the controller gain) varies from 0 to $\propto$. Clearly mark the zeros and poles. **5 Marks**

Based on the root-locus plot, evaluate the overall stability of the closed-loop system. **2 Marks**

Ques: 4 (a) Describe the Bode plot and its use in analyzing the frequency response of a control system.

2 Marks

(b) Interpret the meaning of the Gain and Phase margin in the context of system stability. Discuss how these margins relate to the system's robustness. **3 Marks**

(c) Plot the Bode plot for the given open loop transfer function **5 Marks**

$$\frac{4(1+2S)e^{-\frac{S}{2}}}{(S+1)(\frac{S}{5}+1)}$$

Ques: 5 You are tasked with tuning a proportional-integral-derivative (PID) controller for a temperature control system in a chemical reactor. The transfer function of the process is given by:

$$\frac{K_C}{S(S+2)(S+4)}$$

After performing some experiments, you obtain the ultimate gain (K_u) of 10 and the ultimate period (P_u) of 3 minutes.

Using the Ziegler-Nichols (Z-N) method, calculate the values of proportional gain (K_p), integral time (τ_i) and derivative time (τ_d) for the PID controller. Explain briefly how these values will affect the performance of the control system. **5 Marks**

Ques: 6 Consider a chemical processing plant with a complex reactor system that requires precise temperature control. To achieve this, a cascade control system is implemented.

The primary controller (Controller 1) regulates the flow rate of a heat transfer fluid through a heat exchanger to control the temperature of the reactor. The secondary controller (Controller 2) measures the temperature of the reactor and adjusts the set point for Controller 1.

(a) Draw a block diagram representing the cascade control system. Clearly label the components, including Controller 1, Controller 2, the heat exchanger, and the reactor. **2 Marks**
(b) Derive the transfer function of the cascade system for the regulatory condition **3 Marks**
(c) What are the drawbacks and advantages of cascade system? 2 for each. **2 Marks**

Ques: 7 Describe the basic concept of Smith predictor (Dead time compensator). Draw a block diagram representing the Smith predictor control system. Clearly label the components, including the Smith predictor, the plant, and the controller. **3 Marks**