BIRLA INSTITUTE OF TECHNOLOGY AND SCIENCE, PILANI
Second Semester 2017-2018
Comprehensive Examination
CHE F342: Process Dynamics and Control

Date: 1st May **2018** **Time**:8.00 – 11.00 A.M. **Maximum Marks**: 120

1. **(15 Marks)** The set point of the control system shown in Fig Q1 is given a step change of 0.1 unit.

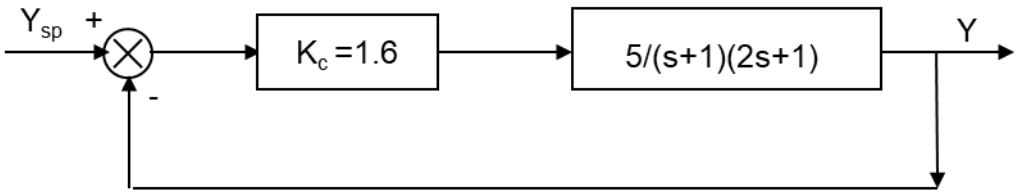

Fig Q1

Determine
(a) The maximum value of Y and the time at which it occurs
(b) The offset
(c) The period of oscillation

2. **(15 Marks)** (a) What is BIBO stability criterion? Define stability for linear transfer function models and state-space models?
(b)The state-space model of the system is given by

$$\frac{dx_1}{dt} + 3x_1 - x_2 - u_1 + 2u_2 = 0$$

$$\frac{dx_2}{dt} - 2x_1 + 3x_2 - 2x_3 - 2u_2 = 0$$

$$\frac{dx_3}{dt} - x_2 + 3x_3 + 5u_3 = 0$$

Determine the stability of this system.
(c) Using Routh Test determine the value of Kc for which the system shown in Fig Q2 will be stable.

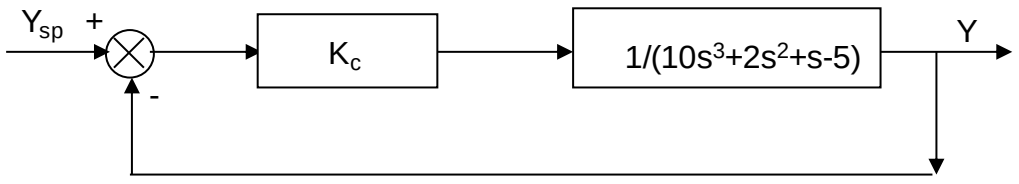

Fig Q2

3. **(30 Marks)** (a) What is Bode stability criterion? Explain gain margin (GM) and phase margin (PM) with a neat diagram.

(b) In the control system shown in Fig Q3 the transfer functions are $G_c = K_c$, $G_v = 1/(10s+1)$, $G_p = 1/(s+1)$, $G_{m1} = e^{-\theta s}$, $G_{m2} = 1/(s+1)$. The gain K_c is increased until the system oscillates continuously at a frequency of 3 rad/min. Calculate the value of time delay θ.

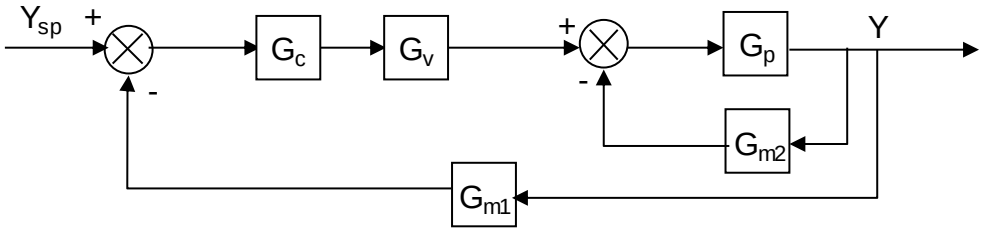

Fig. Q3

(c) For a system with $G_c = K_c[1+(1/2s)]$, $G_v = 1$, $Gp = 1/(s+1)^2$, $Gm = 1$, determine the value of K_c for a Phase Margin of 30^o. What is the Gain Margin in this case?
(d) Obtain the Z-N settings of a PID controller for a system with $G_p = e^{-1.02s}/(s+1)$, $G_v=G_m=1$, $G_d=3/(5s+1)$ using Bode method and Direct Substitution (DS) method. Use Taylor approximation for time delay term in case of DS method.

4. **(15 Marks)** (a) Explain the terms: Bias, Proportional Band, reset time, offset.
(b) A closed-loop system has following transfer functions:

$$G_C = 3,\ G_V = 1,\ G_P = \frac{10}{(8s^2 + 24s + 2)},\ G_M = 1.$$

Obtain the closed-loop response of the system for a unit step change in the set point. What is its value at t = 4 time units and what is the offset?

5. **(15 Marks)** (a) Explain the time integral criteria and simple performance criteria for controller tuning. (b) Find the gain of a proportional controller that produces a closed loop response for a second order system with decay ratio equal to ¼. The process is described by

$$G_p = \frac{1}{s^2 + 3s + 1},\ \ G_v = 1,\ G_m = 1.$$

6. **(15 Marks)** (a) Define the terms: sensor, transmitter, transducer.
(b) Write the equation to specify the size of a valve in terms of its capacity. Draw valve characteristics and show their equations.

7. (**15 Marks**) A liquid storage tank has two inlet streams with mass flow rates w_1 and w_2 and an exit stream with flow rate w_3. w_3 is established by a valve on the outflow line according to $w_3 = Cvh$ where h is the liquid level in the tank and Cv is the valve constant.. The tank is 2.5 m tall and 2m in diameter. The steady state values are w_1 = 120 kg/min, w_2 = 100 kg/min and h = 1.75m.
   (i) What is the steady state value of w_3 and value of valve constant Cv?
   (ii) If w_1 is changed from 120 kg/min to 100 kg/min, what will be the final value of the tank level?

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