BIRLA INSTITUTE OF TECHNOLOGY AND SCIENCE, PILANI
Second Semester 2016-2017
Comprehensive Examination
CHE F342: Process Dynamics and Control

Date: 12th May **2017** **Time**:8.00 – 11.00 A.M. **Maximum Marks**: 120

***Note*:** The question paper consists of two parts. **Part A** is of 30 marks and of 45 Minutes duration. **Part B** question paper can be collected only after submission of Part A answer sheet.

PART – A

Time: 45 Minutes **Marks: 30**

ID NO: **NAME:**

Answer the following questions in the space provided. Each answer bit carries 1 mark.

1. List three objectives of process control.
   Ans. i)
   ii)
   iii)

2. Degrees of freedom is defined as_____ _____.

3. What is the time constant for a tank operating at 10 m head, 5 m^3/min outflow through a valve and has a cross section area of 20 m^2? Ans. _____

4. After a time of 4 time constants the process reaches to_____ of its ultimate value.

5. Natural period of oscillation of the system determines _____ of the system.
6. Small value of damping factor means _____

7. Name any two inherently second order systems.

8. Interaction adds _____ to the system.

9. For a system $\dot{x} = Ax + Bu,\ y = Cx$ the state and process transfer function matrices are _____ and _____ respectively.

10. Name of a process giving inverse response is _____.

11. Direct or reverse actions are relationships between _____ and _____.

12. What is integral windup?

13. Mention the drawbacks of derivative action.

14. Proportional band characterizes the range _____ _____.

15. Why derivative action is not recommended for level control?

16. What are Ziegler-Nichols settings for a PI controller?

17. Name the different time integral performance criteria measures and give their mathematical expressions.

18. When to go for ITAE criterion?

19. A unit impulse response of a 1st order lag process with time constant τ and steady state gain K_p is given by _____.

20. A thermometer inititially at 100°C is dipped at t = 0 into an oil bath maintained at 150°C. If the recorded temperature is 130°C after 1 minute, then the time constant of the thermometer (in minute) is _____.

21. A step change of magnitude 2 is introduced into a system having the transfer function $G(s) = 2/(s^2+2s+4)$. The rise time and percentage overshoot are _____ and _____, respectively.

22. A unit gain 2nd order underdamped process has a period of oscillation 1 seconds and decay ratio 0.25. The transfer function of the process in standard form is _____.

23. The initial value ($t=0^+$) of the unit step response of the transfer function $G(s) = (s+1)/(2s+1)$ is _____.

24. The time constant of a unity gain 1st order plus time delay process is 5 minutes. If the phase lag at a frequency of 0.2 rad/min is 60°, then the time delay (in minutes) is _____.

25. Using Skogestad Harl-Rule, the SOPTD model for a process described by the exact transfer function

$$G(s) = \frac{5(1-s)e^{-s}}{(10s+1)(4s+1)(s+1)(0.2s+1)}$$ is _____.

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Time: 2 hour 15 minutes **PART – B** **Marks: 90**

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1. (***15 Marks***) Perform the degrees of freedom analysis for a constant volume CSTR with one inlet and one outlet stream. The inlet stream contains only component A. Component B is produced by a simple liquid phase irreversible exothermic chemical reaction A⟶B. The rate of reaction is first order with respect to component A. A cooling medium must be used to remove heat Q so as to keep the temperature of the CSTR at the desired level. The reaction rate constant is a function of temperature. Outline all assumptions you made while deriving the model of the system.

2. (***15 Marks***) Develop the transfer function $G(s) = \dfrac{H'(s)}{Q'(s)}$ for the liquid-level system shown in Fig. Q2. At steady state, the inlet flow rate is 43 m^3/hr and the level is 1 m. The resistance R is linear. The tank has three vertical walls and one which slopes at an angle α from the vertical as shown. The distance separating the parallel walls is 1 m. If a unit step change is given in inlet flow rate, what will be the level after 1 hour? Given R = 1 hr/m^2, $\alpha = 45^o$, B = 2 m.

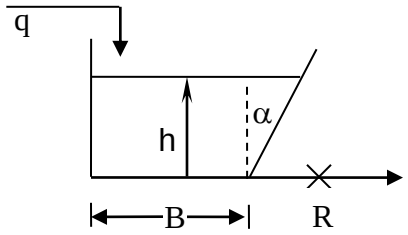
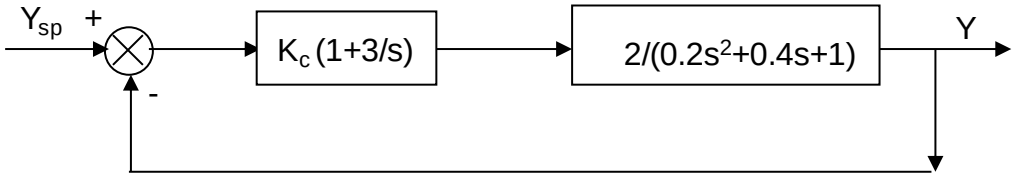


Fig. Q2

3. (***10 Marks***) Obtain the closed loop response (servo) for a First-order system having a PID Controller. Assume Gv=Gm=1. Show that the offset is eliminated in this case.

4. (***10 Marks***) For the control system shown below, find the limit of Kc for which the system will be stable. Use Routh Stability Criterion.



5. (***10 Marks***) A closed-loop system has following transfer functions:

$$G_C = \mathrm{K_C}\left(1+\frac{1}{0.25\mathrm{s}}\right),\ G_V = \frac{1}{s+3},\ G_P = \frac{1}{(s^2+2s+2)},\ G_M = \frac{1}{s+5}.$$

Find the number of separate root loci, number of asymptotes, center of gravity and the angle of the asymptotes for potting the root locus diagram (you need not have to plot).

6. (***10 Marks***) Step test in a system has generated the following unit step response data. Obtain the FOPTD model of the system from the process reaction curve. Design a PI controller for the system using Bode Stability Analysis. Compare the result with the PI controller that can be designed using Direct Synthesis method.

t	0	0.25	0.5	0.75	1.0	1.25	1.5	2.0	2.5	3.0	3.5	4.0	∞
y	0	0.07	0.20	0.34	0.47	0.57	0.66	0.79	0.87	0.92	0.95	0.97	1.0

7. (***10 Marks***) Using low- and high frequency conditions, develop the asymptotic Bode diagram for the PID controller

$$G_c(s) = K_c(1+\frac{1}{s}+0.1s).$$

Clearly show the corner frequencies and the slopes of the asymptotes along with the AR and φ curves in the rough sketch of your plots.

8. (***10 Marks***) For a control system with

$$G_C = \mathrm{K_C}\left(\frac{2\mathrm{s}+1}{0.1\mathrm{s}+1}\right),\ G_V = \frac{2}{0.5\mathrm{s}+1},\ G_P = \frac{0.4}{s(5s+1)},\ G_M = 1,\ G_d = \frac{3}{5s+1}$$

(a) Calculate the value of Kc that provides a phase margin (PM) of 30°.
(b) What is the gain margin when Kc = 10?

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Name: _____ ID No.:_____