Indian Institute of Technology Kharagpur 22-11-2018
Department of Chemical Engineering Time: 3.0 Hrs
End Sem, Autumn 2018-19 Full Marks: 50
Subject: Instrumentation and Process Control (CH31011)

Instructions: Closed book, closed notes examination. Answer all questions. Notations carry their usual meaning. Follow the four step problem solving methodology involving the following four steps: Step-1: Understand the problem. Step-2: Devise a plan. Step-3: Execute your plan. Step-4: Look back.

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1. (3 marks) The transfer function of a process having dead time is given as:

$$G_p(s) = G(s)e^{-\tau s}$$

where G and τ represent the actual process (dead time free part) and actual dead time. If the estimated dead time is τ', derive the open-loop transfer function G_{OL} having uncompensated dead time with P-only controller as:

$$G_{OL}(s) = K_c G(s)e^{-(\tau-\tau')s}$$

in which K_c is proportional gain and $G_f = G_m = 1$.

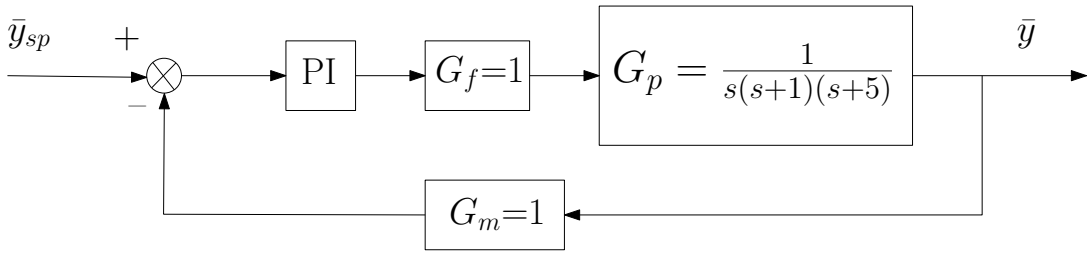
2. (4 marks) Consider a feedback loop having the following transfer functions:

$$G_p(s) = G(s)e^{-\tau s} = \frac{e^{-0.5s}}{0.8s+1}, \quad G_f = G_m = 1$$

Although the model is perfectly known (i.e. $G = G'$), the dead time value is wrongly estimated as 0.45 min. Discuss the impact of dead time on the effectiveness of Smith predictor when the process operates under P-only controller with $K_c = 30$.

3. (2 marks) Configure the override control scheme with a continuous-flow distillation column showing all elements.

4. Consider a closed-loop process shown in Fig. below, in which a PI controller is used to control the system.



   (a) (3 marks) Find the ultimate gain (K_u)

   (b) (2 marks) and ultimate period (P_u).

   (c) (2 marks) Use the Tyreus – Luyben recommended settings and tune the PI controller.

5. (4 marks) Consider a process with the following transfer functions for its primary and secondary elements: Primary element:

$$G_{p1} = \frac{1}{(5s+1)(10s+1)}, \quad G_{m1} = 1$$

Secondary element:

$$G_{p2} = \frac{1}{(s+1)}, \quad G_{m2} = G_f = 1$$

Tune the primary controller (PI) of the cascade control scheme when $K_c = 5$ for the secondary controller (P-only).

6. (3 marks) We know that 'liquid level can be controlled effectively with proportional control'. Mathematically prove it with an example.

7. (2 marks) It is true that the feedforward controllers have the theoretical potential for perfect control. If it is so, then what is the use of combined feedforward-feedback controller?

8. (5 marks) Consider the following characteristic equation:

$$1 + \frac{K_c}{(3s+1)(s+1)}$$

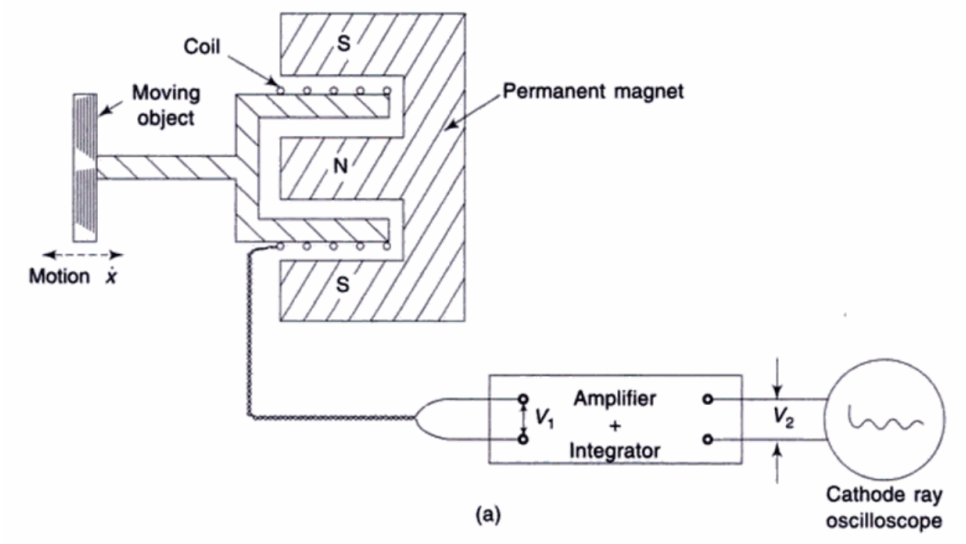
Comment on stability by developing the rough sketch of root locus diagram.

9. (5 marks) Using proper schematics, explain the working principle of a pneumatic proportional controller. Your explanation must show quantitatively how proportional action is achieved.

10. (a) (2 marks) Name different functional elements of an instrument and explain the difference between physical element and functional element.

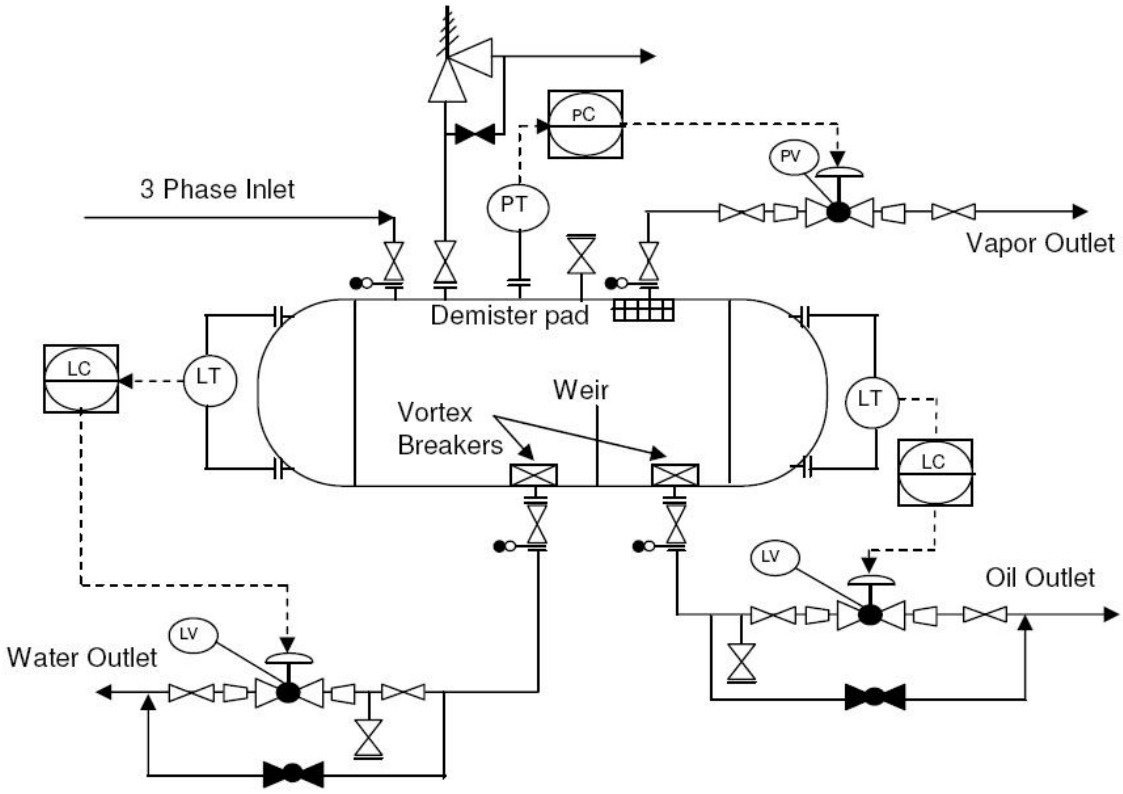
    (b) (4 marks) Consider the equipment shown in the following diagram which is used to measure instantaneous velocity of an object vibrating around a mean position. [1]. As shown in the figure, the movement of the coil with respect to the fixed magnet induces a voltage proportional to the rate of change of magnetic flux which is in turn proportional to the velocity of the coil. This voltage, after appropriate amplification, changes the position of an electron beam in a Cathode Ray Oscilloscope. Identify all functional elements of the instrument with proper reasoning.

[1] Figure taken from *Instrumentation, measurement and analysis* by Nakra and Chaudhry



11. Consider the portion of a process plant as shown in the figure below [2]:
    (a) (1 mark) Draw symbols for process line, pneumatic signal and electrical signals.
    (b) (2 marks) How will you identify the location of an instrument from a P&ID?
    (c) (1 mark) Identify the purpose of the equipment and the associated instrumentation.
    (d) (3 marks) Discuss the functioning of the entire equipment by identifying the purpose of each of the instrument mounted including valves.
    (e) (2 marks) Identify all control loops. Identify the controlled and manipulated variable for each of the control loops. What type of level transmitter has been used in this case?

[2]Figure taken from EnggCyclopedia.com


PC
PV
3 Phase Inlet
PT
Vapor Outlet
Demister pad
LC
LT
Weir
Vortex
Breakers
LT
LC
LV
Oil Outlet
LV
Water Outlet