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INDIAN INSTITUTE OF TECHNOLOGY–KHARAGPUR

End-Autumn Semester 2015-16 (closed book)

Course No.: CH 31011 **Max. Time**: 3 hrs

Course Title: Instrumentation and Process Control **Total Marks**: 50

Instructions: Attempt all questions. Assume, if necessary, clearly stating the reason. Answer all parts of a question together.

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1. (a) How are the pressure-measuring instruments classified? Explain with suitable examples. Describe the principle, construction and working of an ionization gage. **[2+2]**

(b) What do you mean by transducer? Describe with a suitable diagram, the construction and working principle of a LVDT. **[2.5]**

(c) Starting from the force balance equation for a rotameter, derive the condition that needs to be satisfied for "density compensation" of the float. **[2]**

(d) Compare and contrast a thermocouple with a thermistor as a temperature transducer. **[2]**

(e) Explain with a suitable diagram, the working principle of level measurement using a Bubbler Tube. **[2]**

2. (a) A system is described by the following set of state equations:

$$\frac{dx_1}{dt} = f_1(m_1, m_2, d_1, d_2) \text{ and } \frac{dx_2}{dt} = f_2(m_1, m_2, d_1)$$

Perform the degrees of freedom analysis to make the system *exactly specified.*

(b) When the P-only controller is employed around a first-order system, what changes we notice in the closed-loop behavior [when $G_f(s) = G_m(s) = 1$] in terms of:

(i) time constant **[2.5+4+(3+1)+3+5=18.5]**

(ii) static gain

(c) The mathematical model of a process with two inputs (f_1 and f_2) and two outputs (y_1 and y_2) is given as:

$$\frac{dy_1}{dt} = a_{11}y_1 + a_{12}y_2 + b_{11}f_1(t) + b_{12}f_2(t)$$

$$\frac{dy_2}{dt} = a_{21}y_1 + a_{22}y_2 + b_{21}f_1(t) + b_{22}f_2(t)$$

All the variables are in deviation form. The initial conditions are given as: $y_1(0) = y_2(0) = 0$. Develop the transfer function model of this process and the corresponding block diagram.

(d) Consider a second-order process with the transfer function: $G_P = \dfrac{4}{s^2 + 5s + 1}$. Considering $G_m = 2$ and $G_f = 3$, employ a PI controller with $K_C = 10$ and $\tau_I = 0.01$, and analyze the stability of the closed- loop system.

(e) Tune the PI and PID controllers using the Ziegler-Nichols approach for a system having the following open-loop transfer function:

$$G_{OL}(s) = \frac{K_C e^{-0.15s}}{0.5s + 1}$$

3. (a) Discuss the relative merits and demerits of the followings: Routh-Hurwitz criterion, time-integral performance criterion, one-quarter decay ratio criterion and Ziegler-Nichols method.

(b) Develop the following control configurations for a distillation column: (i) cascade controller, and (ii) ratio controller **[4+(2+1)+2+(4+1)+5=19]**

(c) Develop the block diagram for a process employed with a ratio controller.

(d) Consider the following open-loop transfer function (time in min):

$$G_{OL}(s) = \frac{0.8 K_C e^{-1.74s}}{(5s+1)(10s+1)(15s+1)}$$

Tune the P-only controller with a phase margin of 26^0. Perform the stability analysis if the true value of dead-time is 6 min, instead of 1.74 min.

(e) Consider the following open-loop transfer function:

$$G_{OL}(s) = \frac{K_C}{(s+1)(2s+1)(4s+1)}$$

Analyze the stability developing the Nyquist plot when $K_C = 50$.

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