Department of Chemical Engineering, Indian Institute of Technology, Delhi

Subject: CHL261 (Instrumentation and Process Control)

Minor 2 (20 Marks), Duration: 1 hr (Open Book: Chemical Process Control by George Stephanopolous & Process System Analysis and Control by Donald Coughanowr), Solve any one question completely and first part (a) of the other.

Note: Use Routh-Hurwitz criteria and Pade first order approximation whenever required.

1) For the typical feedback control system (see FIGURE 1) with $G_P(s) = 1/[(s+1)(2s+1)]$, $G_c(s) = K_c(1+\tau_D s), G_m(s) = 1$ and $G_f(s) = 1$
   a) Show how you would adopt the usual root-locus method for variation in controller gain to the problem of obtaining the root locus diagram for variation in τ_D for $K_c = 2$. (**Hint:** rearrange the expression in a equivalent form such that the rules framed for variation in K_c can be applied as it is) **(5 marks)**
   b) Plot the root locus diagram for variation in τ_D for the control system for $K_c = 2$. Show imaginary and real axis with dotted lines (------), indicate the scales, explain each step clearly and plot the root-locus with solid lines (——) and suitable arrows. **(8 marks)**
   c) For a step input in set-point, $\tau_D = 0.5$ and $K_c = 2$, calculate the offset. **(2 marks)**

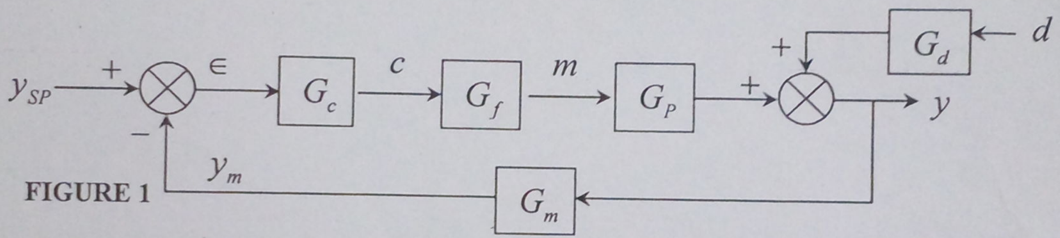

FIGURE 1

2) The control system such as shown in FIGURE 2 is often used to achieve the better control of a given process than that obtained using usual feedback control system. In this, the actual process output is compared with that predicted using the formulated process model. Clearly, the formulated process model will have several assumptions and thus the output of it will not be same as that with actual process.
   a) Derive closed loop transfer functions for both the servo and regulatory problems. **(5 marks)**
   b) For a process actually having first order dynamics with time lag $[G_P(s) = e^{-s}/(1+s)]$, a control engineer used a simplified model of just a first order dynamics [i.e. $\widetilde{G_P}(s) = 1/(1+s)$] and designed the feedback control system as shown in FIGURE 1 [$G_c(s) = K_c, G_m(s) = 1, G_f(s) = 1$] to maintain the offset < 0.2 in a **servo problem**. (i) He calculated the theoretical value of K_c and used for a real process. (ii) However, he found that the response of real process is unstable for calculated value of K_c. So, as a rule of thumb he gradually decreased the value of K_c in order to stabilize the system. By doing this, system does become stable but the offset kept on increasing above 0.2. (iii) After lot of thinking he modified the feedback control system as shown in FIGURE 2 which he claims to be providing a better control action compared to that of former. Check the calculations of a control engineer. **(2 + 4 + 4 marks)**

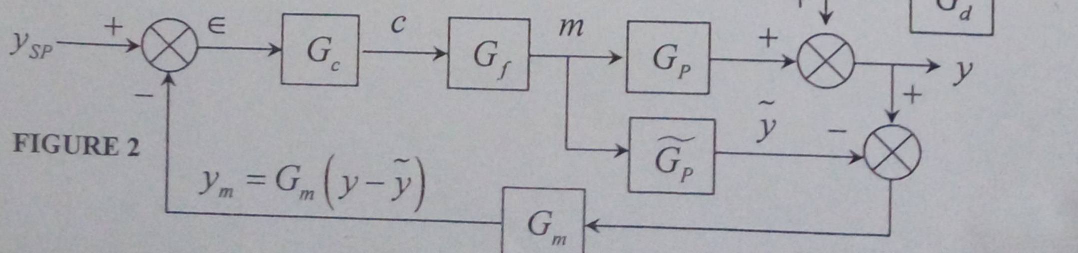

FIGURE 2