Process Dynamics and Control
Practice Problems

1. Consider the following process model,

$$\tilde{G}_p = \frac{2(-2s+1)}{(12s+1)(2s+1)}$$

   (a) Design an IMC for this process (Design for setpoint tracking and use simple factorization).

2. Consider the following process model and the controller designed using IMC.

$$\tilde{G}_p = \frac{2}{(10s+1)} \qquad (G_c)_{IMC} = \frac{(10s+1)}{2(\alpha s+1)}$$

   If the true process model is,

$$G_p = \frac{3}{(10s+1)}$$

   (a) What is the closed-loop transfer function Y/Y_{sp}?

   (b) Considering a step change in setpoint, will this control system have offset? Justify your answer.

3. Short Answer Concept Questions

   (a) The following two controllers were designed for the same process using the standard IMC design procedure.

$$G_{c1} = \frac{(2s+1)(4s+1)}{(3s+1)^2} \qquad G_{c2} = \frac{(2s+1)(4s+1)}{(8s+1)^2}$$

   Which controller is more robust? Justify your answer.

   (b) Consider direct synthesis design of a controller for the following process,

$$G_p = \frac{2e^{-4s}}{(11s+1)}$$

   Is a desired closed-loop transfer function of $Y/Y_{sp} = 1/(\alpha s+1)$ achievable for this process? Justify your answer.

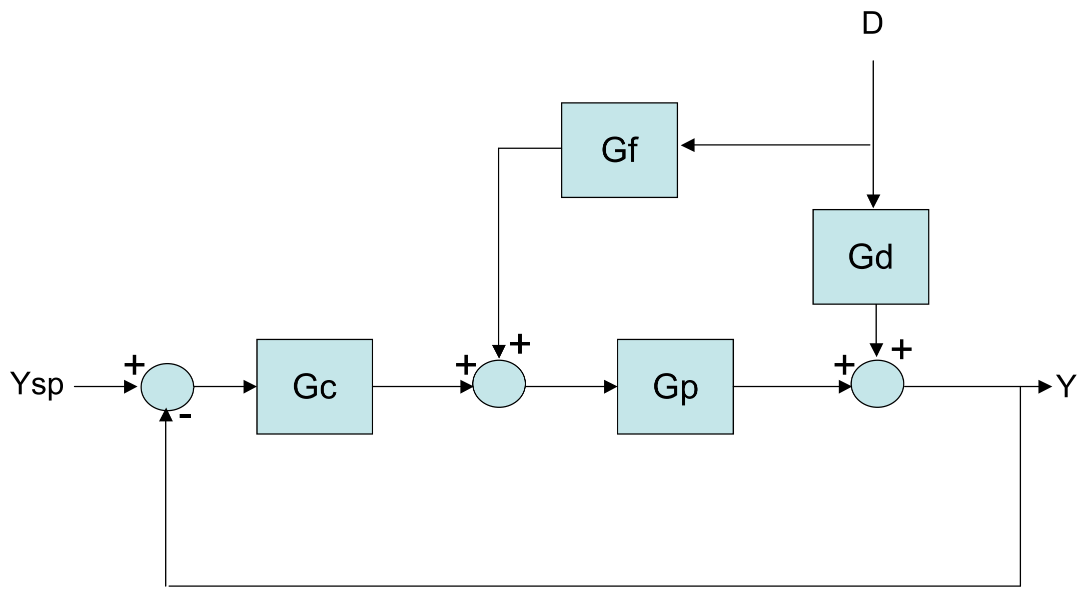
   (c) Indicate whether or not the following controller designs are appropriate (i.e. proper, causal, stable). Use YES if they are appropriate and NO if they are not. If they are not appropriate, indicate why.

   (i) $G_c = \dfrac{(3s+1)(5s+1)}{(6s+1)^2}$ (ii) $G_c = \dfrac{(3s+1)(5s+1)}{(6s+1)e^{-3s}}$

   (iii) $G_c = \dfrac{2(s+1)^2}{-24s^2+2s+1}$ (iv) $G_c = \dfrac{-2(s+1)^2}{24s^2+10s+1}$

   (v) $G_c = \dfrac{s+1}{(5s+1)(\alpha s+1)}, \alpha > 0$

4. (25 pts) In an effort to impress your Boss, you propose the following modified control structure to account for disturbances that you can measure. Your new feedback loop has two controllers. G_c is the standard feedback controller. G_f is a controller that adjusts the process based on the measured disturbance.



The process models are

$$G_p = \frac{1}{5s+1} \qquad G_d = \frac{1}{6s+1}$$

(a) Show that the transfer function Y/Y_{sp} for your modified control structure is the same as Y/Y_{sp} for the standard feedback loop.

(b) If the desired closed-loop response to a setpoint change is $\frac{Y}{Y_{sp}} = \frac{1}{10s+1}$ find an expression for the controller G_c using direct synthesis.

(c) Is this a P, PI, or PID controller? If so, what are K_c, τ_I, and τ_D?

(d) Find an expression for the closed-loop transfer function relating the output to the disturbance Y/D.

(e) Assume that the desired closed-loop response to a disturbance is $(Y/D)_d = 0$. Solve for the controller G_f that will give this desired response. (Note: Your formula for direct synthesis does not apply.)

(f) Is this a P, PI, or PID controller? If so, what are K_c, τ_I, and τ_D?