Process Dynamics and Control
CHEN 461, Spring 2013

Homework #8
SHOW YOUR WORK!

1. Consider the following closed loop transfer function:

$$Y = \frac{G_p G_v G_c K_m}{1 + G_p G_v G_c G_m} Y_{sp} + \frac{G_{L_1}}{1 + G_p G_v G_c G_m} L_1 + \frac{G_{L_2}}{1 + G_p G_v G_c G_m} L_2$$

with $K_m = 1$ and the first order process dynamics for each block given in the following table.

Block	Gain	Time Constant
Process	1	5
L_1 Disturbance	2	5
L_2 Disturbance	1	5
Valve	2	1
Thermocouple	1	0

(a) If we use a proportional controller, what values of K_c will guarantee stability of the system?

(b) Brent, Hank, and Lacy design the following controllers for this process. Brent designs a proportional only controller, while Lacy and Hank have designed PI controllers. For each of the controllers, simply indicate if it will be stable or not, and if you think the performance will be acceptable or not. You can use a simulation to check your answer if you like (don't include the plots). However, remember that you will not have simulink on an exam.

Person	K_c	τ_I
Brent	-0.25	N/A
Lacy	1	0.1
Hank	2	2

2. Consider the same transfer function as that in question 2, but now with slightly different process dynamics, as per the following table.

Block	Gain	Time Constant
Process	1	5
L_1 Disturbance	2	5
L_2 Disturbance	1	5
Valve	2	1
Thermocouple	1	1

   (a) Assuming proportional only control, find upper and lower bounds on K_c which will guarantee stability using simulations. At the upper bound, what is the period of oscillation produced in the system?

   (b) Again, assume proportional control only. Find the upper stability limit using the direct substitution method. Give K_{cu} (also called K_{cm}), and P_{cu}. Does this agree with the previous result?

3. Controller Design: Consider the following first order plus time delay (FOPTD) process,

$$G_p = \frac{2e^{-5s}}{10s+1}$$

   Our plan is to design a PI controller for this process.

   (a) Find the Cohen-Coon tuning parameters for the PI controller

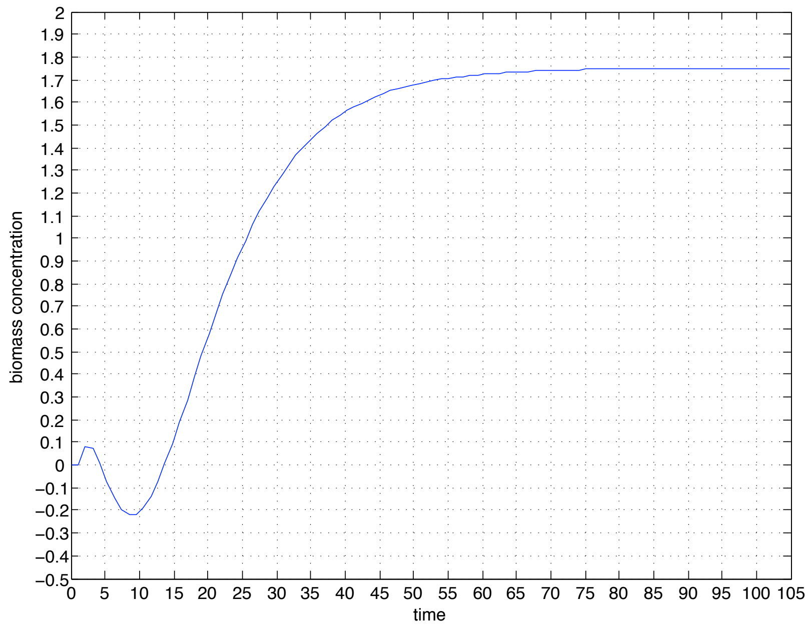
   (b) Find the Z-N tuning parameters for a PI controller. Note: you can solve for K_{cu} and P_{cu} mathematically (with a 1/1 Pade approximation), or by simulation.

   (c) Simulate the response of both controllers to a setpoint change using the real process model. Comment on the overall controller performance and any differences between the two design techniques.

4. A biochemical reactor has the following model relating the biomass concentration to the dilution rate:

$$G_{BR} = \frac{1.75(-3s+1)(-5s+1)e^{-1.25s}}{(10s+1)(4s+1)^2}$$

The step response for the process is shown in the following figure. Design a series of



PID controllers and compare their response using the following steps. *NOTE: You should save all your work from this question for use in a future homework problem.*

(a) Fit a FOPTD model to the step response using the graphical approach. In particular, identify k_p, θ, and τ_p

(b) Design a PI and a PID controller using the Cohen-Coon tuning method.

(c) Design a PI and a PID controller using the ITAE method.

(d) Build a simulink model for all the controllers and simulate the response of your control loops. Use the "true" model G_{BR} as the process G_p, not your approximate model. Produce a figure showing all of the responses. Discuss the differences between the two tuning methods for PI and for PID. Overall, which tuning method and controller (PI or PID) do you recommend for this system?

(e) Take your selected controller from above and fine tune the controller parameters to get what you feel is the best performance possible. Produce a figure comparing the performance of your tuned controller with your selected controller from above.