Process Dynamics and Control – ChE 436
Fall 2018, Section 001
Exam 1 (Practice) – Closed Book, Notes, 1 Page (Front only) Allowed, In Class (50 minutes)

Name___________________________________

Exam 1, ChE 436 name______________________

(Scores: _____/10 _____/20 _____/40 _____/30 _______ Total)

1. (10 pts, 5 min) A control system is composed of an actuator, sensor, and a controller. List at least 3 examples of control systems and detail the 3 elements of each:

Control System 1:

Sensor:

Actuator:

Controller Objective or Set Point:

Control System 2:

Sensor:

Actuator:

Controller Objective or Set Point:

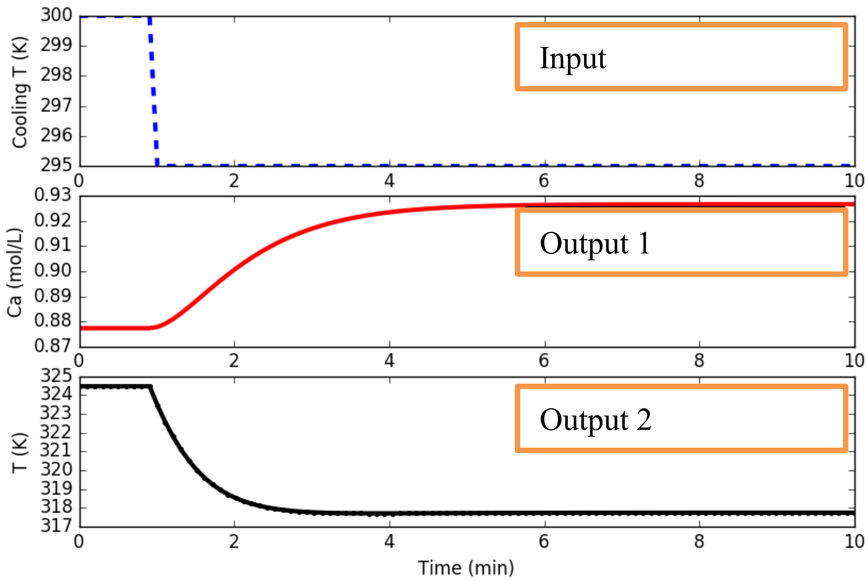
Control System 3:

Sensor:

Actuator:

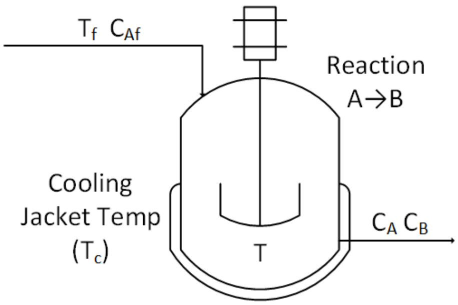
Controller Objective or Set Point:

2. (20 pts, 10 min) A process has the following step response with one input and two outputs.



Find the process parameters (K_p, τ_p, and θ_p) for each response assuming a FOPDT model.

3. (40 pts, 20 min) A reactor is used to convert a hazardous chemical A to an acceptable chemical B in waste stream before entering a nearby lake. This particular reactor is dynamically modeled as a Continuously Stirred Tank Reactor (CSTR) with a simplified kinetic mechanism that describes the conversion of reactant A to product B with an irreversible and exothermic reaction. Because the analyzer for product B is not fast enough for real-time control, it is desired to maintain the temperature at a constant set point that maximizes the consumption of A (highest possible temperature).



(a) On the diagram, indicate which quantities are manipulated (MV), controlled (CV), and potential disturbance variables (DV).

(b) Write the transient species balance to calculate C_A and an energy balance to calculate T.

(c) Calculate the steady state values:

$C_{A\_ss}=$ ________________

$T_{ss}=$ ________________

(d) Linearize the transient species balances. Use deviation variables:

$$C'_A = C_A - C_{A\_ss}$$
$$T' = T - T_{ss}$$

Reduce the final expression to the following form:

$$\frac{dC'_A}{dt} = \alpha_1 C'_A + \alpha_2 T' + \alpha_3 T_c'$$

$$\frac{dT'}{dt} = \beta_1 C'_A + \beta_2 T' + \beta_3 T_c'$$

List the numeric values of α_{1-3} and β_{1-3} with the associated units:

$\alpha_1 =$ ____________________ $\beta_1 =$ ____________________

$\alpha_2 =$ ____________________ $\beta_2 =$ ____________________

$\alpha_3 =$ ____________________ $\beta_3 =$ ____________________

4. (40 pts, 20 min) A process has a time constant of 5 seconds and a dead time of 3 seconds. A step change on the process input (Δu) is implemented to change the output by an anticipated amount (Δy). Determine how long it takes from the initial step input to get to:

0.5 Δy: ______________________sec

0.9 Δy: ______________________sec

0.95 Δy: ______________________sec

1.0 Δy: ______________________sec

A linear first-order equation is the following:

$$\tau_p \frac{dy}{dt} = -y + K_p\, u(t-\theta_p)$$

For a step change, Δu, the analytical solution for a first-order linear system (no dead-time) is:

$$\tau_p \frac{dx}{dt} = -x + K_p\, u(t)$$

$$x(t) = K_p \left(1 - \exp\left(-\frac{t}{\tau_p}\right)\right) \Delta u$$

With dead-time, the solution to a step response becomes:

$$y(t) = x(t-\theta_p) S(t-\theta_p) = K_p \left(1 - \exp\left(-\frac{t-\theta_p}{\tau_p}\right)\right) \Delta u\, S(t-\theta_p)$$

where $S(t-\theta_p)$ is a step function that changes from zero to one at $t = \theta_p$. In this case, $x(t)$ is the solution without dead-time and $y(t)$ is the solution with dead-time.