CHEM-E7140 Process Automation exam: October 28, 2016

1 Answer shortly

a) Describe the structure of the distributed automation system: Basic functions, supportive functions, and network and fieldbus systems (1p)
b) Describe the information flow from the field level to the control room and back: Different devices and cards. (1p)
c) Describe response of second-order systems to step-input. Consider the general transfer function for the second order system. (1p)
d) Describe the principle of cascade control (1p)
e) Internet of Things (IoT) in process automation (1p)

2 Dynamic modeling

The Process

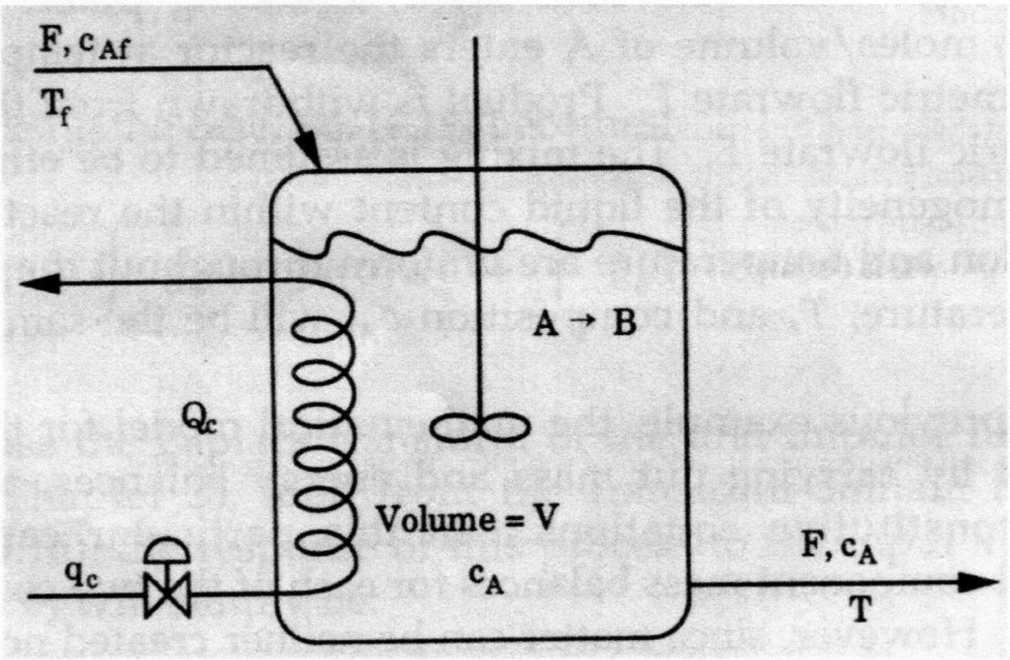


Figure 1. The nonisothermal CSTR

The nonisothermal continuous stirred tank reactor (CSTR) is shown in Fig. 1, in which a first-order, irreversible chemical reaction A → B (with a reaction rate constant *k*) is taking place. Feed material containing c_{Af} moles / volume of A enters the reactor at temperature T_f, and constant volumetric flowrate *F* Product is withdrawn from the reactor at the same volumetric flowrate *F*. The mixing is assumed to be efficient enough to guarantee homogeneity of the liquid content within the reactor. This means that composition and temperature are uniform throughout the reactor and that the exit temperature, T, and composition c_A, will be the same as within the reactor.

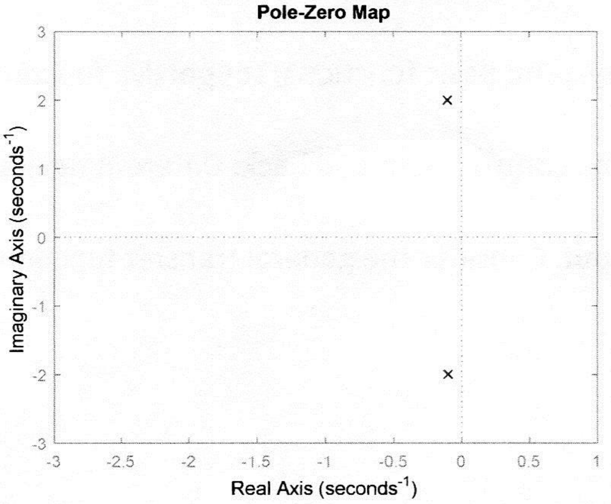
Please formulate

1. Overall mass balance, (1p)
2. Component mass balance and (2p)
3. Energy balance (2p)

for this process.

3 Process dynamics

a) Some process has the following pole-zero configuration:



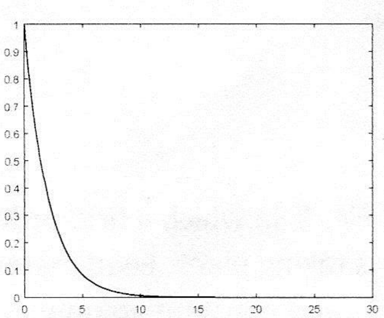
Which of the following arguments describe the process best (0.5p)? What process the pole-zero plot could describe (0.5p)?

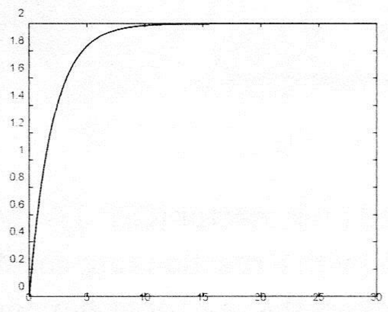
a. The process is unstable.
b. The Process is on the stability limit. The oscillation of the response doesn't die.
c. The process is asymptotically stable, but the response has decaying oscillation.
d. The process is minimum phase process.

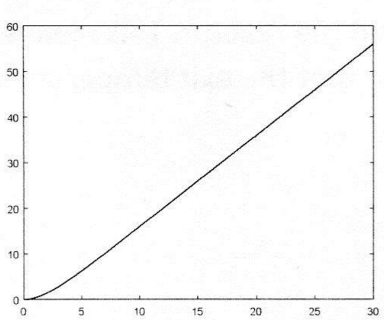
b) The transfer function of some process is defined as

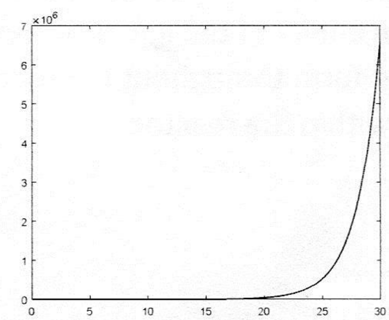
$$G(s) = \frac{2}{2s+1}$$

The process is tested with the Unit Impulse signal. Which of the pictures below describe the response best? (1p)


a)


b)


c)


d)

c) Find the solution $x(t)$ of the differential equation (2p)

$$\ddot{x} + 2\dot{x} + 5x = 3, \; x(0) = 0, \; \dot{x}(0) = 0$$

Please use the computer for the following parts:

4 a) PI tuning

Teemu Teekkari has got a summer job from process industry and was asked to tune the PI controller of the following process: (3p)

$$G(s) = \frac{12}{(s+1)(s+7)(s+2)}$$

Tune the process for the PI controller according to the Ziegler-Nichols tuning rule based on the step response of the process.

Use the values: * step input; step time: 1, Initial value: 0, Final value: 1

Table 1: Ziegler-Nichols tuning rule based on the step response of the process:

Controller	Gain K	Integration time T_I	Derivation time T_D
P	$\frac{1}{K}\frac{\tau}{\alpha}$	-	-
PI	$0{,}9\frac{1}{K}\frac{\tau}{\alpha}$	3.33α	
PID	$1{,}2\frac{1}{K}\frac{\tau}{\alpha}$	2α	0.5α

b)

The dynamic behavior of the liquid level *h* in the conical storage tank system shown in Figure 2 can be shown to be represented by:

$A = \pi r^2 = \pi\left(\frac{Rh}{H}\right)^2$, $\frac{dh}{dt} = \frac{\alpha F_i}{h^2} - \beta h^{-3/2}$, where parameters are defined by: $\alpha = \frac{1}{\pi}\left(\frac{H}{R}\right)^2$, $\beta = c\alpha$

F_i is the inlet flowrate, the manipulated variable. Obtain a linear model for this system (2p)

$$f(x,y) \approx f(x_s, y_s) + \left.\frac{\partial f}{\partial x}\right|_{\substack{x=x_s\\y=y_s}} (x - x_s) + \left.\frac{\partial f}{\partial y}\right|_{\substack{x=x_s\\y=y_s}} (y - y_s)$$

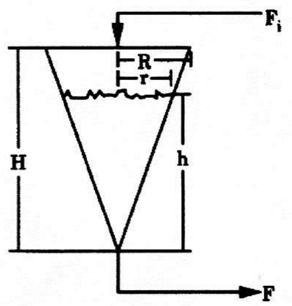
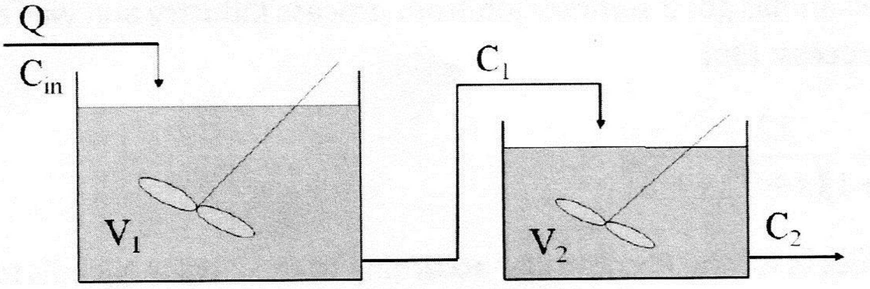


Figure 2 The conical tank system

5 Simulation

Let us consider the following tank system, where the tanks are perfectly mixed. The flow Q and the volumes V_1 and V_2 are constant:



$Q = 1\ m^3/s$

$V_1 = 0.5\ m^3$

$V_2 = 0.2\ m^3$

a) Simulate the system in Matlab or Simulink with the initial conditions of $C_1 = 0$ and $C_2 = 0$. Make a step change of 0.5 mol/m^3 to the input concentration at t = 10. (3p)

b) Derive the state-space model of the system. Obtain also the transfer function form of the system. Obtain the response (hand calculate) in time domain $y(t)$ when unit-step input is used. (2p)

Save your model with name prob1.mdl.