Process control and automation (CHEM-C2140)
Exam

April 11, 2022

Q1) Describe the operation principles of three different (based on the different physical measurement) flow measurements (max 100 words) (2.5p).

Q2) What means feedforward control? (max 75 words) (1p)

Q3) In the context of the controller design, what means the derivative kick? Which types of controllers it may affect? (max 75 words) (1p)

Q4) Explain the terms manipulated variable, controlled variable and disturbance variable. (max 100 words) (2.5p)

Q5) Essay: What are the working principles of analog and digital signals? How the use of digital signals has transformed the field of process control? (Max 600 words) (5p)

Q6) Sketch by hand the ouput response $y(t)$ of the FOPDT model when the input variable $u(t)$ is that shown in Fig. 1. The FOPDT model has the process gain of $K_\mathrm{p} = 5$, time coefficient of $\tau_\mathrm{p} = 2$ s, and dead time of $\theta_\mathrm{p} = 3$ s. At $t = 0$ s, the output response is at a steady-state value of $y(0) = 30$. Make the sketch for the range of [0, 20] s.

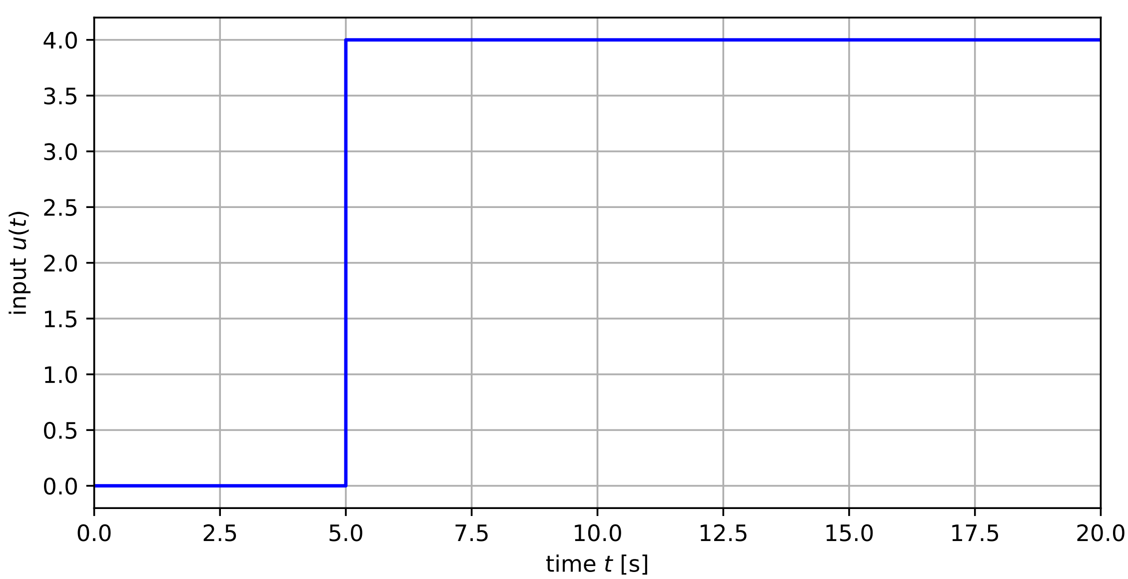

Figure 1: The input variable $u(t)$ during the time window $t \in [0, 20]$ s.

(3p)

Q7) Three mixing reactors are in series (see Fig 2). In reactors, a chemical 1st order irreversible reaction takes place while the density and temperature remain constant.

q_i are the volumetric flow rates and C_{Ai} are the concentrations. Write the differential equations describing the system of the each reactor for the concentration.

a) Write the differential equations describing the system for each reactor when the volume is also assumed to be constant.

b) Write the differential equations describing the system for each reactor. Assume that the volumes in the tanks change as a function of time.

Follow the steps of the systematic model development. State all assumptions that are needed, and pay special attention to the classification of inputs.

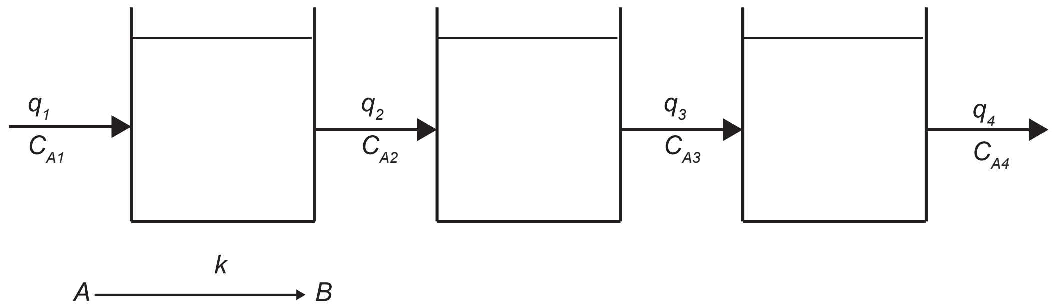

Figure 2: Three mixing reactors are in series.

(8p)

Q8) Let us consider the liquid tank shown in Fig. 3. The physics-based model for liquid level $h(t)$ in the tank is

$$\frac{dh(t)}{dt} = \frac{1}{A}\Big(q_{\text{in}} - q_{\text{out}}\Big),$$

where A is the cross-sectional area of the tank. The volumetric flow rate into the tank is $q_{\text{in}} = cu(t)$, where c is the valve coefficient and $u(t) \in [0, 1]$ is the position of the valve. The actuator of the valve reacts immediately to its control signal, and the length of the inlet pipe is negligible for the process dynamic. The volumetric flow rate at the outlet, q_{out}, is linearly proportional to the liquid level h in the tank, $q_{\text{out}} = rh(t)$, where r is a constant. The density of the liquid is ρ. The model is assume to be a precise representation of the liquid level $h(t)$ in the tank.

Considering the valve position $u(t)$ as the input variable and the tank level $h(t)$ as the output variable, identify the process parameters (i.e., the process gain K_{p}, the process time coefficient τ_{p}, and the process dead time θ_{p}) for the liquid tank without performing a step test.

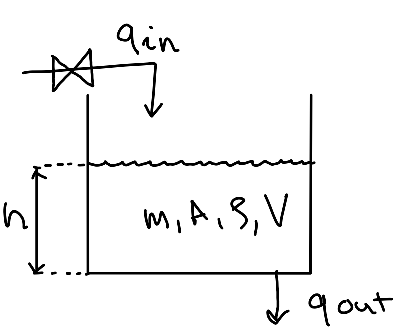

Figure 3: A liquid tank with a hole.

(5p)

Q9) The process follows the following dynamics:

$$\frac{d^2y(t)}{dt^2} + 3\frac{dy(t)}{dt} + 2y(t) = 3u(t)$$

with initial conditions $y(0) = 0$, $y'(0) = 0$.

Calculate the transfer function $G(s) = Y(s)/U(s)$ and determine the process response $y(t)$ when the excitation signal $u(t)$ is:

a) Unit step function

(2p)

b) Ramp function

(2p)