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Process Dynamics – CPN321

Semester Test 2

Chemical Engineering
Engineering and the Built Environment

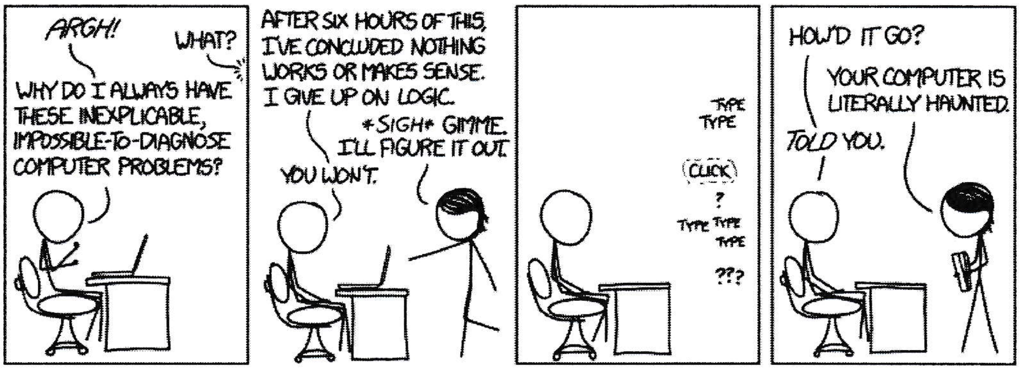
Examiner: Carl Sandrock

Date: 2017-10-09

Duration: 90 minutes   Total: 90   Total Pages: 6

Instructions – Read carefully

• Answer all the questions. • This is a closed book test. All the information you may use is contained in the paper. • You may use the computer • Make sure that you motivate all your answers and write legibly.



xkcd.com

1 Second order dynamics

Consider the following differential equation. u' and x' are deviation variables of u and x respectively. a, b and c are all positive.

$$a\frac{\mathrm{d}x'}{\mathrm{d}t^2} + b\frac{\mathrm{d}x'}{\mathrm{d}t} + cx'(t) = u'(t) \tag{1}$$

1. Find the transfer function between u and x. $\boxed{5}$

2. Find the gain, time constant and damping coefficient of the system in terms of a, b and c. $\boxed{10}$

3. When u is moved suddenly from 2,3 kg/h to 4,0 kg/h, x moves from 12,1 °C and eventually ends up around 15,8 °C. What is the gain of the process? $\boxed{5}$

4. Plant personnel describe the step response as having a slight overshoot and a rise time of 10 minutes. Draw a sketch showing the response and indicate the rise time, overshoot and time constant. What does this information tell you about the damping coefficient of the system? $\boxed{10}$

Total for question 1: $\boxed{30}$

2 Complex system dynamics

Due to limitations in software used on site, you have decided to approximate a model of a piece of equipment as a second order plus dead time system as follows:

$$\frac{(s-1)}{(3s+1)^3(s+2)} \approx \frac{Ke^{-\theta s}}{(\tau_1 s+1)(\tau_2 s+1)} \tag{2}$$

1. Find K, τ_1 and τ_2 using Skogestad's half rule $\boxed{20}$

2. Sketch a qualitative response of the original system to a step input. Indicate key features of the response on the graph. Mention the gain, poles and zeros. $\boxed{10}$

3. An engineer on site criticizes your approximation by saying "Your approximation no longer exhibits inverse response". Is she right? Is this a serious problem? $\boxed{5}$

4. Explain why Skogestad's half rule could not be used for the system in equation 1 with reference to the nature of the poles. $\boxed{5}$

Total for question 2: $\boxed{40}$

3 Multivariable system representations

Consider the following state space description of a system:

$$\frac{\mathrm{d}x}{\mathrm{d}t} = Ax + Bu \quad (3)$$

$$y = Cx + Du \quad (4)$$

with

$$A = \begin{bmatrix} -1 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & -\frac{1}{2} \end{bmatrix} \quad B = \begin{bmatrix} 2 & 0 \\ 0 & 2 \\ 0 & 1 \end{bmatrix} \quad C = \begin{bmatrix} 1 & \frac{3}{2} & 0 \\ \frac{1}{2} & 0 & 1 \end{bmatrix} \quad D = \begin{bmatrix} 0 & 0 \\ 0 & 0 \end{bmatrix}$$

1. How many inputs, states and outputs does this model have? Motivate your answer. $\boxed{5}$
2. Obtain a transfer function matrix for this model. Derive any equations that you use in the process and write each matrix element as a simplified rational function of s. $\boxed{10}$
3. Determine whether the system is stable without referring to the transfer function model. Show your working. $\boxed{5}$

Total for question 3: $\boxed{20}$

Full Marks $\boxed{90}$

LaTeX 2_ε
www.latex-project.org