Process Dynamics – CPN 321

Semester Test 2

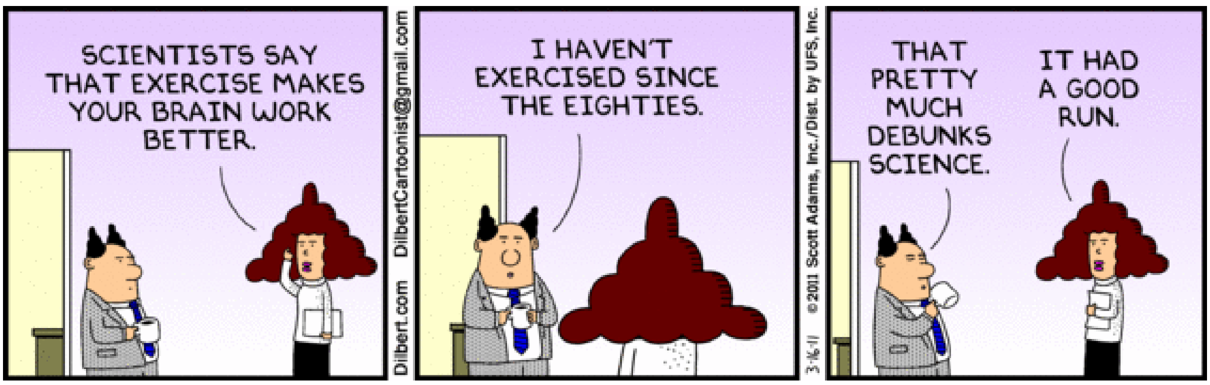
Chemical Engineering
Engineering and the Built Environment

Examiner: Carl Sandrock

September 2011 | 90 minutes

Instructions – Read carefully

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



www.xkcd.org

1 Linearisation

The following equations represent a chemical system.

$$\frac{\mathrm{d}}{\mathrm{d}t}[x(t)y(t)] = 2x(t)^2 + 3\frac{y(t)}{x(t)} \tag{1}$$

$$\frac{\mathrm{d}y(t)}{\mathrm{d}t} = \sqrt{y(t)} + \frac{x(t)-1}{2} \tag{2}$$

1. Rewrite the system as a linearised model in terms of deviation variables. $\boxed{4}$
2. Rewrite the linearised system in matrix form. $\boxed{2}$
3. Consider the right hand side of equation 1. Use a graph on the attached graph paper to indicate the accuracy of the linear approximation given that y stays near the steady state value ($\bar{x} \approx -1.23$, $\bar{y} \approx 1.24$) $\boxed{4}$

$\boxed{\textit{10}}$

2 First order response

A tank system described by equation 3

$$\frac{\mathrm{d}h}{\mathrm{d}t} = 3F_{in}(t) - 2h(t) + 1 \tag{3}$$

is subjected to a change in F_{in} as shown in figure 1.

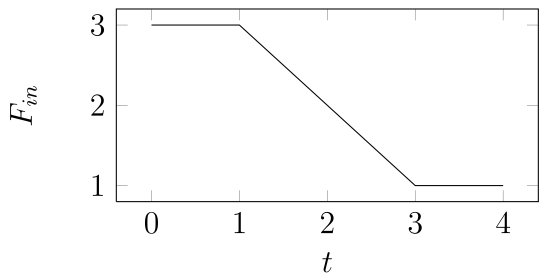


Figure 1: Flowrate for system response in question 2

1. If the system starts at steady state, calculate the initial height h_0. $\boxed{1}$
2. Express the input signal shown in figure 1 as a linear combination, with optional time-shifting, of steps and/or ramps. Use qualitative graphs to explain your answer. $\boxed{3}$
3. Sketch the system's response ($h(t)$) to the input signal qualitatively and indicate the time constant on your graph. $\boxed{2}$
4. Calculate the system response ($h(t)$) analytically. $\boxed{4}$

$\boxed{\textit{10}}$

3 Second order response

Consider the following equations describing a heat exchanger system with feedback control. a and b are positive constants.

$$\frac{\mathrm{d}T}{\mathrm{d}t} = aF$$
$$\frac{\mathrm{d}F}{\mathrm{d}t} = K\left(\frac{\mathrm{d}T}{\mathrm{d}t} + b(T - T_S)\right)$$

1. Find a single second-order differential equation that describes the response of T to changes in T_S. $\boxed{2}$
2. Determine the values for K for which the system will be stable. $\boxed{4}$
3. Sketch a qualitative step response of the system for $K = 2$. $\boxed{2}$
4. Sketch a qualitative step response for the system given critically damped behaviour. $\boxed{2}$

$\boxed{\mathit{10}}$

Full Marks $\boxed{30}$

LaTeX 2_ε
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