Process Dynamics – CPN321

Semester Test 2

Chemical Engineering
Engineering and the Built Environment

Examiner: Carl Sandrock

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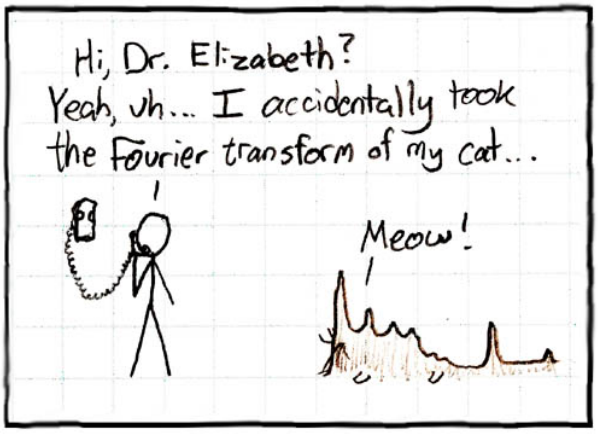
Instructions – Read carefully

• 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.



www.xkcd.org

1 Linearisation

Rewrite the following system as a linearised model in terms of deviation variables. (10)

$$\frac{\mathrm{d}}{\mathrm{d}t}[x(t)y(t)] = 2x(t)^2 + 12\frac{y(t)}{x(t)} \tag{1}$$

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

(10)

2 Chemical system dynamics

The following linearised differential equations represent the behaviour of a chemical system in terms of deviation variables.

$$3\frac{\mathrm{d}^2w(t)}{\mathrm{d}t^2} = 2w(t-d) + 5C_A(t) \tag{3}$$

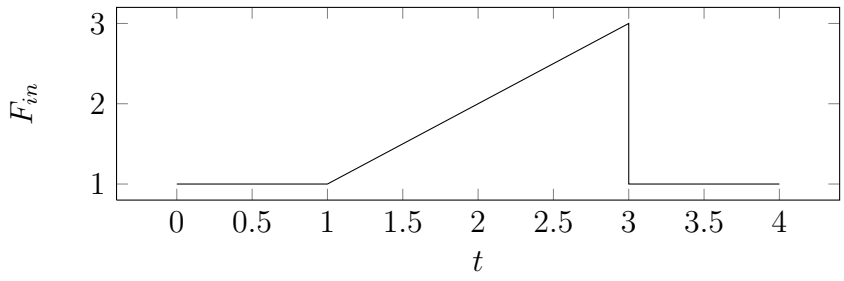
$$4\frac{\mathrm{d}C_A(t)}{\mathrm{d}t} = 4w(t) + 6C_A(t) + 8F(t) \tag{4}$$

1. Transform these equations to the Laplace domain and determine the transfer function between F and w. (10)
2. Assuming $d = 0$, write the relationship between F and w in state space form (10)

(20)

3 Input modelling

Write the following function as a combination of ramp functions and step functions. (10)



(10)

4 Inverse Laplace

The following equations describe a system in the Laplace domain

$$(s+1)y(s) = e^{-2s}x(s) \tag{5}$$

$$(s^2 + 2s + 2)x(s) = (s-1)u(s) \tag{6}$$

1. Determine the time-domain function representing the response of y to a step of height 1 in u starting at time $t = 1$. [10]

2. Draw a qualitative sketch of this response, referring to the poles and zeros of the transfer function between y and u to explain what you drew [5]

15

5 System dynamics

Consider the following differential equation:

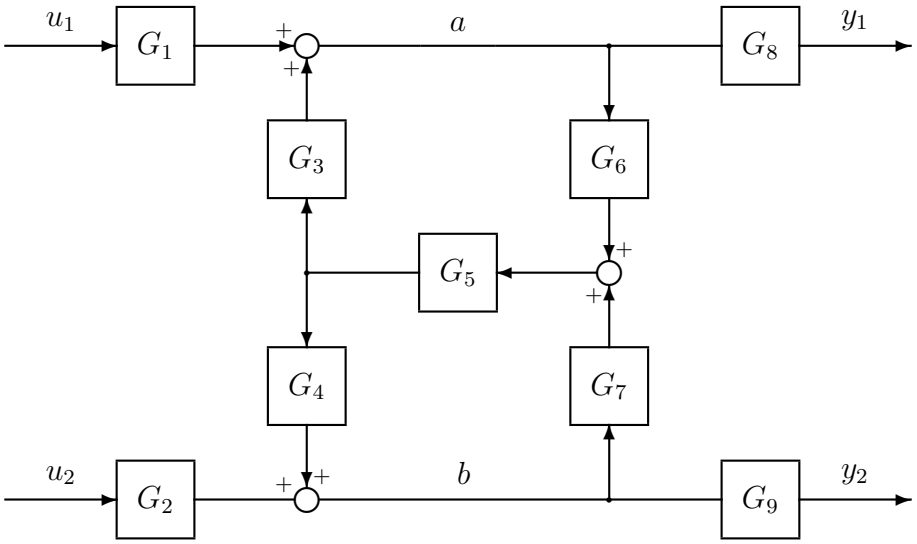
$$5\ddot{x}(t) = x(t) + \frac{x(t)}{1+k} - \theta\dot{x}(t) + 3u(t) \tag{7}$$

1. Determine the steady state gain, time constant and damping coefficient of this system [5]

2. If $k = 1$, for what value of θ will the system exhibit an overshoot of 10%? [5]

10

6 Block diagrams



1. Write down the (scalar) transfer function from u_1 to y_2 from the following block diagram. [15]

2. Find the matrix G such that $\mathbf{y} = G\mathbf{u}$. You do not have to simplify the matrix if it is made up of other matrices. [10]

25

Full Marks [90]

LaTeX 2_ε
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