ENGLISH

University of South-Eastern Norway

EXAMINATION INFORMATION PAGE

Home exam

Subject code: FM1220	Subject name: Automatic Control	
Responsible subject teacher: Finn Aakre Haugen	Campus: Porsgrunn	Faculty: TNM
Exam given in WISEflow (date and time): 09:00 on 14th December 2021	Submission time in WISEflow (date and time): 13:30 on 14th December 2020	
No. of exam problems: 13	No. of attachments: None	No. of pages incl. front page and attachments (if any): 5

Aids and collaboration:

Permitted aids: All aids are allowed.

	Yes	No
Is it an individual exam?	☒	☐
Is it allowed to collaborate with other persons?	☐	☒

Description of individual examination and illegal cooperation will be found at [my.usn.no](my.usn.no)

Criteria for the answers:

Font type: Not specified.	Font size: Not specified.	Line spacing: Not specified.
No. of words (min/max): Not specified.	Maximum no. of pages excl. front page and attachments: Not specified.	

Source reference: No source references are expected in the answer.

Other important information:

You cannot call on the teacher for help about interpreting or understanding the task.

If you miss some prerequisites for solving a problem, you must define the appropriate prerequisites yourself and state them in the answer, so that you can still solve the problem.

The % number for each problem is the weight of that problem when deciding the grade of the exam.

Problem 1 (5 %) Mathematical block diagram

Given the following mathematical model of a system:

$$Ay'' = B\sqrt{y'} + Cu + Dd$$

where y is the output variable, u is the control variable, d is the disturbance variable, and A, B, C, and D are model parameters. y' means time-derivative. y has initial value y_{init}. y' has initial value y'_{init}. Draw a detailed mathematical block diagram for this model.

Problem 2 (8 %) Simulation algorithm

Given the model presented in Problem 1. y is limited to the range $[y_{\text{min}}, y_{\text{max}}]$. Derive an Euler-based "pseudo" simulation algorithm for y more or less ready to be implemented in a loop in a program (but it is not expected that you code the algorithm in a program during the exam). The time step is dt. You do not have to define any numerical values.

Problem 3 (5 %) Adaptation of a dynamic model to data

Explain in general term (i.e. you do not have to assume any specific case) how you can adapt a dynamic model in the form of a differential equation of specified order to given time-series of the input and the system of the pertinent system.

Problem 4 (6 %) Transfer function of PID controller

Derive the transfer function from control error to control signal of a PID controller. (Show each step of the derivation.)

Problem 5 (8 %) Process dynamics

For each of the systems: (1) Time-constant with time-delay. (2) Integrator with time-delay:

- Present its model as a transfer function.
- Draw (sketch) the unit-step response. Indicate how the model parameters appear in the response.

Problem 6 (10 %) PID tuning with Ziegler-Nichols

The following Python program is a simulator of a PI control system for a process:

http://techteach.no/courses/fm1220/2021/exam/sim_control_sys.py

Download the program, and open it in a programming environment, e.g. Spyder. Tune the PI controller using the (original) Ziegler-Nichols method. Then, run a simulation to demonstrate the stability of the control system. Is the stability better or worse than the Ziegler-Nichols "one quarter decay ratio" stability? (Include proper plots in your answers.)

Problem 7 (5 %) Transfer function of a control system

Given a process with transfer function $P(s)$ controlled by a controller with transfer function $C(s)$. Derive the transfer function from setpoint, y_{sp}, to control error, e. (Show each step of the derivation.) This transfer function has a name – which?

Problem 8 (5 %) Stability margins

Given a stable control system with controller gain $K_c = 2$.

- Assume that the control system shows sustained oscillations if K_c is increased to 5. What is the gain margin, GM, of the control system?
- With $K_c = 2$, the control system has sustained oscillations with period 90 s if the time delay in the loop is increased by 10 s. What is the phase margin, PM, of the control system?
- Does the control system have acceptable stability? Give a reason for your answer.

Problem 9 (12 %) Averaging level control

The following Python program simulates an averaging level control system:

http://techteach.no/courses/fm1220/2021/exam/averaging_level_control.py

Download the program, and open it in a programming environment, e.g. Spyder.

In the program, the PI controller controller gain (Kc) and integral time (Ti) are calculated using the Skogestad method, from specified maximum acceptable level change (denoted d_h_max in the program) due to assumed maximum step change of the inflow (d_F_in_max) – as explained in the course.

The program generates three plots:

- Plot 1: Level (h) response due to a step change of inflow (F_in). Also, d_h_max is plotted.
- Plot 2: Sinusoidal inflow (F_in) and the corresponding response in outflow (F_out).

- Plot 3: Bode plot of the magnitude or gain of the transfer function (H_fout_fin) from F_in to F_out. In the Bode plot, the frequency of the sinusoid in plot 2 is indicated with a red line.

1. (6 %) Run the downloaded program. From Plot 1 you should see that the specification of the maximum acceptable level change is satisfied, with a nonzero margin. What is the size in meters of that margin?
2. (6 %) In the downloaded program, change the period (t_p_F_in) of F_in from 600 s to 1250 s. Then, run the program. What is the ratio between the F_out amplitude and the F_in amplitude as seen from Plot 2? Explain that this ratio can also be observed in the Bode plot in Plot 3.

Problem 10 (8 %) Cascade control system

Draw a P&I diagram of an example, which you select by yourself, of cascade control system. What is the purpose of the secondary loop in your example?

Problem 11 (6 %) Feedforward control

For the process model given in Problem 1, derive a feedforward controller for this process. What quantities must be known for the feedforward controller to be realizable? (Show the detailed derivation of the feedforward controller in your answer.)

Problem 12 (10 %) Frequency response

Derive the frequency response – both amplitude (magnitude) and phase – of the following transfer function:

$$H(s) = \frac{K_i}{s} e^{-\tau s}$$

Problem 13 (12 %) Control structure of a process line

Figure 1 shows an uncontrolled process line. In tank T3, gas is generated from the liquid. Pumps are used to manipulate liquid flows (F1-F4). Gas flow (F5) is manipulated with a valve. The production flowrate is manipulated with flow F2. Draw a P&I diagram of a control structure of the process line. Assume pertinent setpoints have been specified.

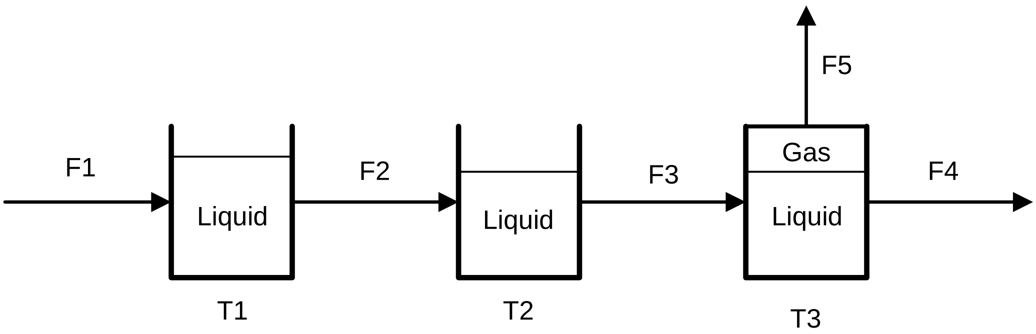

Figure 1: Process line.