ENGLISH

University of South-Eastern Norway

EXAMINATION INFORMATION PAGE

Home exam

Subject code: FM1220	Subject name: Automatic Control	
Responsible subject teacher: Finn Aakre Haugen (finn.haugen@usn.no)	Campus: Porsgrunn	Faculty: TNM
Exam given in WISEflow (date and time): 09:00 on 22 February 2021	Submission time in WISEflow (date and time): 13:30 on 22 February 2021	
No. of exam problems: 11	No. of attachments: None	No. of pages incl. front page and attachments: 3

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

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.

In problems about running Python programs, relevant generated plots must be included in your answer.

The % number for each assignment indicates the weight of the assignment in the examination.

Problem 1 (5 %) Piping & Instrumentation Diagram
Draw a Piping & Instrumentation Diagram of a temperature control system of a process. You can select by yourself the process to be temperature controlled. It is assumed that the controller is accessible in the field. The instruments are numbered with parallell numbering with three digits. Both the control signal and the measurement signal are digital.

Problem 2 (5 %) Simulation algorithm
Given the following mathematical model of a system:

$$a*y'' = b*y' + c*y + d*u$$

where y is the output variable, u is the input variable, and a, b, c, and d are model parameters. Derive an Euler-based "pseudo" simulation algorithm of the model more or less ready to be implemented in a loop in a program (but it is here not expected that you code the algorithm in a program during the exam). Make any assumptions not stated above by yourself.

Problem 3 (5 %) Dynamics
Assume a system with gain -3 (minus three), time constant 10 s, and time delay 2 sec. Sketch (manually) principally the step response of the system assuming the input step has amplitude 4 appearing at time 50 sec. Before the step appears, the system output is at rest with value 15.

Problem 4 (10 %) PID tuning for level control
Assume a level control system with PI controller for a water tank with cross-sectional area A = 5 m2. The level controller manipulates the inflow in units of m3/s. The outflow is a disturbance. Tune the PI controller so that the closed loop time constant is 100 s. (Intermediate calculations must be shown.)

Problem 5 (15 %) PID tuning with the Good Gain method
The following Python program is a simulator of a PI control system for a process:
http://techteach.no/courses/fm1220/2020/exam/sim_control_sys.py

a. (10 %) Download the program, and open it in a programming environment, eg. Spyder. Tune the PI controller using the good Gain method. Run a simulation that (hopefully) shows that the control system has acceptable stability after the controller setting.
b. (5 %) Find from a simulation the value of the steady state control error with the PI controller. Then, de-activate the I-term of the controller while keep the P-term unchanged; hence you now have a P controller. Find from (another) simulation the value of the steady state control error with the P controller. (If you have not succeeded in tuning the PI controller in Problem a, you can use these settings: Controller gain = 2 and Integral time = 20 s.)

Problem 6 (5 %) Cascade control
Draw a block diagram of a general cascade control system having three levels of control loops.

Problem 7 (10 %) Feedforward control
Describe briefly two different practical applications of feedforward control. You should include drawings (select any form you like) of the control systems.

Problem 8 (5 %) Transfer function
Given the following differential equation model: Ay' + B*y + C*u + D*d = 0. y is the output variable, u is the input variable, and d is the interference variable. Find the transfer function, Hu(s), from u to y and the transfer function, Hd(s), from d to y. (Intermediate calculations must be shown.)

Problem 9 (15 %) Transfer function of a control system
Given a process which is represented with a time-constant transfer function. The process is controlled with a PI controller. Derive the tracking transfer function of the control system. What is the order of the control system? Write the equation from which you can calculate the poles of the control system (however, you are not supposed to actually calculate the poles in this problem). What is the requirement of the poles of the control system for the control system to be asymptotically stable?

Problem 10 (15 %) Analysis of a control system
The following Python program analyzes a PI control system for the wood chip tank, which is similar to an example that has been studied in various contexts in this course:
http://techteach.no/courses/fm1220/2020/exam/stab_analysis_of_control_sys.py
Download the program, and open it in a programming environment, e.g. Spyder. In the program, the PI controller controller gain (Kp) and integral time (Ti) are specified.

a. (7.5 %) Set the controller gain to 5. Run the program. After the program is run, the gain margin (GM) and the phase margin (PM) are displayed in a Bode diagram. What are GM and PM? What is GM expressed as a "normal” number (not in decibels)? Is the stability of the control system acceptable as seen from GM and PM?
b. (7.5 %) Tune the PI controller with the (original) Ziegler-Nichols' method. What are the values of GM [not in decibels] and PM now? Do they have acceptable values?

Problem 11 (10 %) Control structure of a process line
Figure 1 shows an uncontrolled process line consisting of a serial connection of liquid tanks. Draw a Piping & Instrumentation Diagram of the control structure of the process line based on the following specifications: The production rate (-flow) is controlled by controlling F1 to its setpoint. The mass balance of the liquid in each tank should be maintained using pumps as actuators. The gas pressure is controlled to a setpoint using a control valve as actuator.

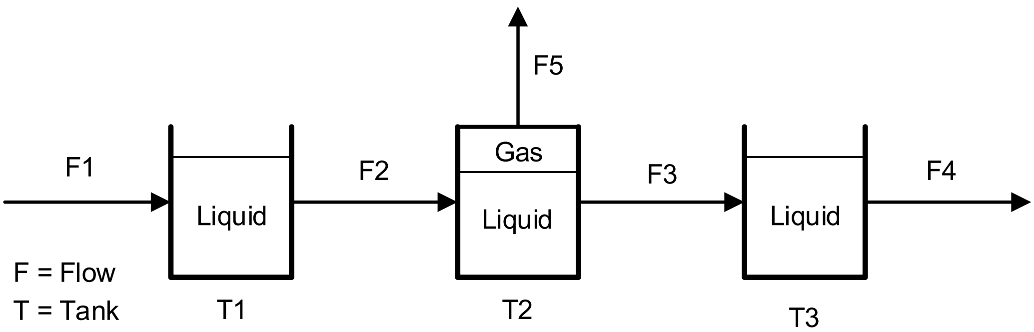

Figure 1