ENGLISH

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 16th December 2020	Submission time in WISEflow (date and time): 13:30 on 16th December 2020	
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](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
Given a level control system for a water tank with inlet and outlet. The level control is based on manipulation of a pump in the inlet. The controller is accessible via a computer screen in a control room. Both the control signal and the measuring signal are electric. *Draw a Piping & Instrumentation Diagram of the control system.*

Problem 2 (5 %) Simulation algorithm
Given the following mathematical model for a system: a*y' = b*sqrt(y) + c*u, where y is the output variable, u is the input variable, and a, b and c are model parameters. y is limited to the range [y_min, y_max]. y has initial value y_init. y' means time-derivative. sqrt means square root. *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). The time step is dt. You do not have to define numerical values.*

Problem 3 (5 %) Dynamics
Given a system with gain K, time constant T, and time delay Td. The system is initially in steady (static) state, with the value of the output variable, y, equal to y0. At time t0, the system is affected by a step change from u0 to u1 at the input, u. *Plot principally u(t) and y(t) manually in their respective plots, showing how the given information appears in the plots. The origin (0, 0) shall appear in both plots.*

Problem 4 (10 %) PID tuning for averaging level control
Given a level control system with PI controller for averaging level control for a water tank with cross-sectional area A = 50 m2. The largest sudden change that the inflow to the tank can have is 100 L/s. It is specified that this largest change must give a maximum level change of 20 cm. *Tune the PI controller. (Intermediate calculations must be shown.)*

Problem 5 (15 %) PID tuning with Relaxed Ziegler-Nichols' 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, e.g. Spyder. Tune the PI controller using Relaxed Ziegler-Nichols' method. Run a simulation that (hopefully) shows that the control system has acceptable stability after the controller setting.*
b. *(5 %) Run a simulation that demonstrates that the steady state disturbance compensation is perfect. Is this due to the proportional term or the integral term? (No derivation is required in your answer.) (If you have not succeeded in tuning the controller, you can use these PI settings: Kc = 2 and Ti = 20.)*

Problem 6 (5 %) Cascade control
When pumps are used as actuators in level control systems, they are typically flow-controlled. *What can be the purpose of the flow control of the pumps? In such level control systems, which of the general terms primary loop and secondary loop apply to the flow control loop and the level control loop? What may be a tertiary control loop in such a control system?*

Problem 7 (10 %) Feedforward control
Given the following model of a process to be controlled: T*y'= -y + K1*u + K2*d, where y is the output variable, u is the control variable, d is the process disturbance variable, and T, K1 and K2 are parameters. The setpoint of y is y_sp. *Derive a feedforward controller for this process. What quantities must be known for the feedforward controller to be realizable? In general, why is it typically necessary in practice to combine feedforward control with feedback control? (Intermediate calculations must be shown.)*

Problem 8 (5 %) Transfer function
Given the following differential equation model: y''= - a1*y' - a0*y + b*u + c*d, where y is the output variable, u is the input variable, d is the interference variable, and a1, a0, b and c are parameters. *Find the transfer function from u to y. What is the order of the transfer function? (Intermediate calculations must be shown.)*

Problem 9 (15 %) Tuning and analysis of a control system
Given a process with the following transfer function from control signal to measurement signal: Hp(s) = K/s. *Characterize this process in terms of its dynamics (just a single term is expected in your answer). Calculate the gain Kc of a P controller for the process so that the control system gets a time constant of Tc [s]. What is the pole of the control system? Assuming K is negative, does the controller have reverse action or direct action? (Intermediate calculations must be shown.)*

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 %) 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 repeated Ziegler-Nichols' method based on the simulation performed when you run the program in subtask a. *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 F3 to its setpoint. The mass balance of the liquid in each tank should be maintained. Pumps are used as actuators.*

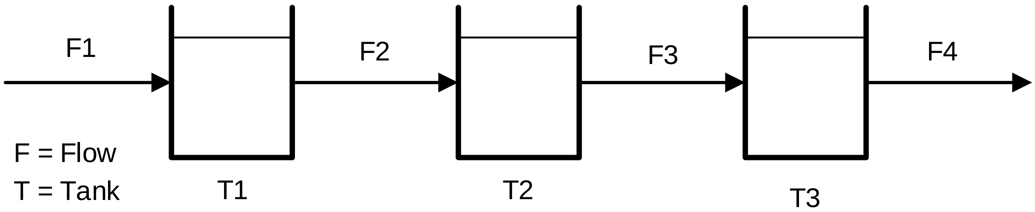

Figure 1