M TEST EXAM THREE

Introduction & Instructions

This is the regular exam of BCS 2024 MAY.

- Duration: 3 **hours**
- Number of problems: **9**
- Allowed material: **Writing gear, calculator**
- Calculation of final scores: $\frac{\textbf{score\_obtained}}{10}$, round to 1 decimal
- Note for grading: correct solutions without reasoning do **not** grant points.

Question 1 (10 pionts)

Give the overall transfer function $H(s) = \frac{Y(s)}{R(s)}$ of this block diagram in Fig. M.1.
Show at least two intermediate steps used to find the solution.

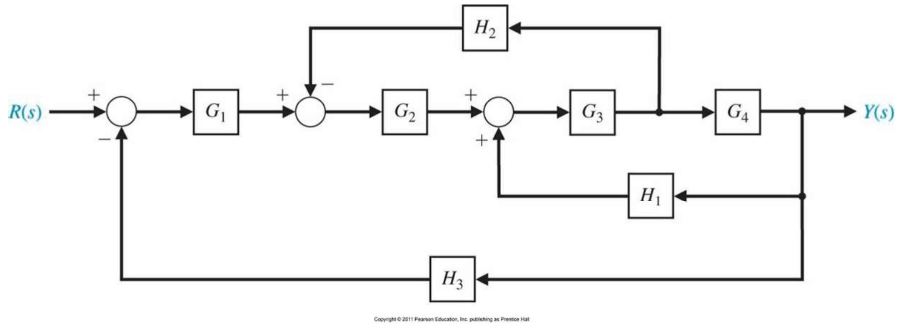

Figure M.1: Block diagram.

Question 2 (10 pionts)

Sketch only the gain part $|H(j\omega)|$ of the Bode diagram of $H(s)$:

$$H(s) = \frac{s(s+100)}{(10s+1)(s+10)}$$

Explain how you obtained your sketch (show intermediate steps).

Question 3 (10 pionts)

The input to system $H(s)$ is a step function. Find the output $x(t)$ of the system if the transfer function $H(s)$ equals:

$$H(s) = \frac{6s^2+2s+8}{s^2+2s+4}$$

Explain how you obtained the solution (show intermediate steps).

Question 4 (15 pionts)

Determine the transfer function $H_P(s)$ and its parameters K_P, τ_P and τ_v from the following step response graph in Fig. M.2.

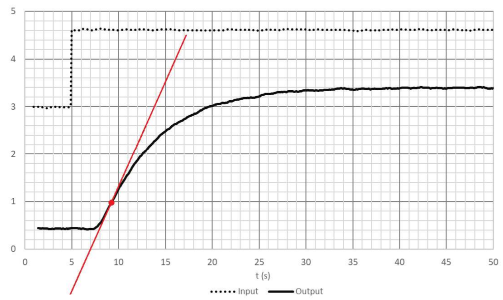

Figure M.2: The step response data

Assume the process to be a **delayed first order process**. The point of inflection and tangent are already drawn. Use the graph in the answer sheet to show how you find the parameters.

Sketch sheet problem 4

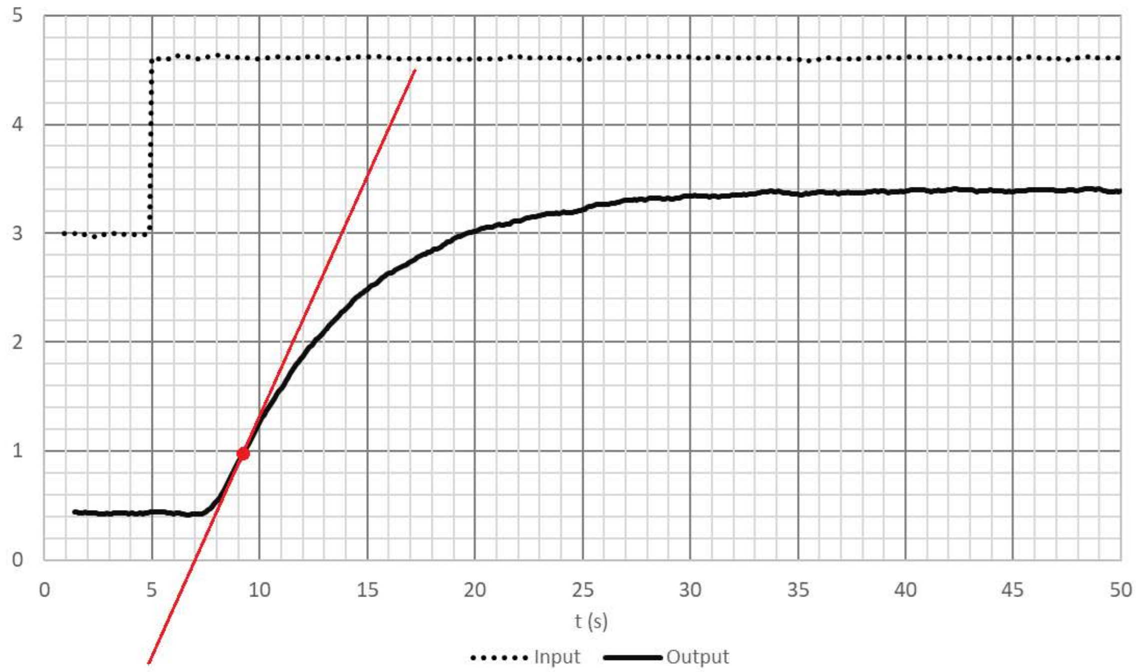

Figure M.3: The step response data

Question 5 (10 pionts)

The three poles and the two zeros in the complex plane of a system $H(s) = \frac{Y(s)}{X(s)}$ are shown below in Fig. M.4. The DC-gain of the system is 3. Determine the differential equation. Explain how you determined the DE.

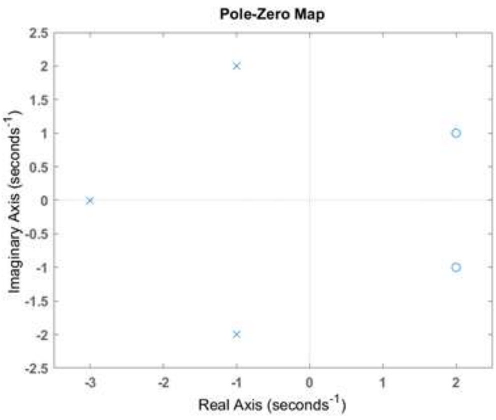

Figure M.4: Pole-zero map

Question 6 (15 pionts)

Given the following Bode diagram in Fig. M.5 of an open loop process with transfer function $G(s)$. The process is placed in a normal feedback loop (negative feedback and unity feedback) and a controller is used with a gain K.

1. The input of the system is given by $u(t) = \cos(0.25t)$. What is the analytical expressions for the output x(t)? Explalin how you obtained your answer.

2. What is the stability of this system? Explain your answer.

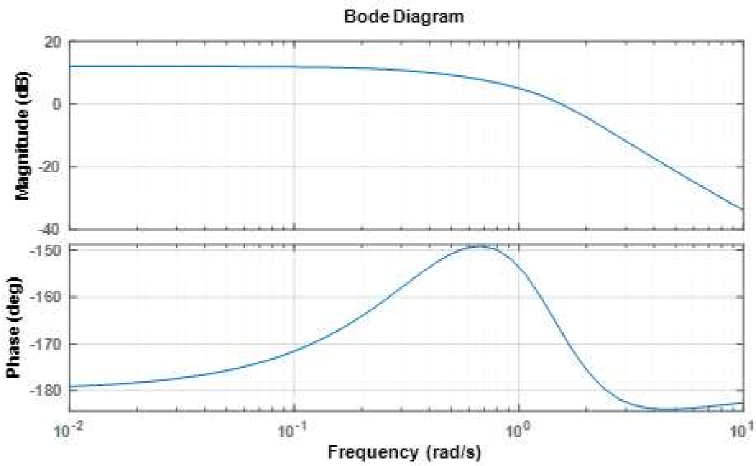

Figure M.5: Bode diagram

Question 7 (10 pionts)

The following Nyquist diagram in Fig. M.6 is obtained from the process $G(s)$ with a P-controller $K = 1$.

$$G(s) = \frac{-s^4 - 12s^2 - s - 1}{0.6s^4 + 2.1s^3 - 2s^2 + 3s + 2}$$

The four open-loop poles of $G(s)$ are located at:

$$-4.4609 + 0.000\mathbf{i} \quad 0.7121 - 1.0517\mathbf{i} \quad 0.7121 + 1.0517\mathbf{i} \quad -0.4632 + 0.000\mathbf{i}$$

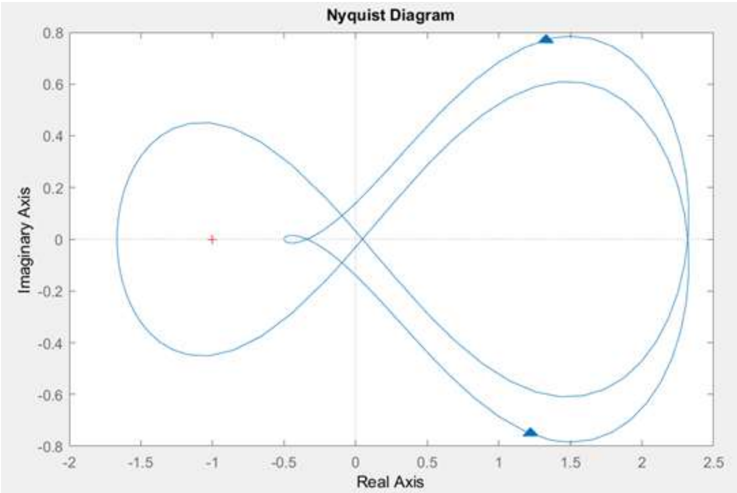

Figure M.6: Nyquist diagram

Question 8 (10 pionts)

What is the Laplace transform of the following function $f(t)$ as shown in Fig. M.7.
Explain how you obtained your answer (show intermediate steps).

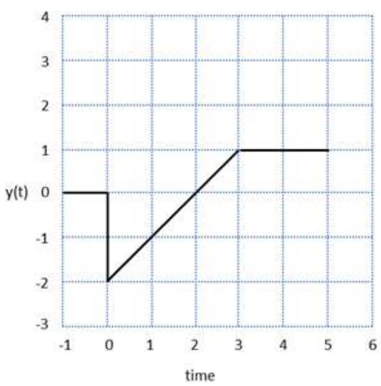

Figure M.7: $f(t)$

Question 9 (10 pionts)

Consider a system with a controller and process and a unity feedback. This controlled system has the following time response on a unit step input (step value 1 at $t = 0$).

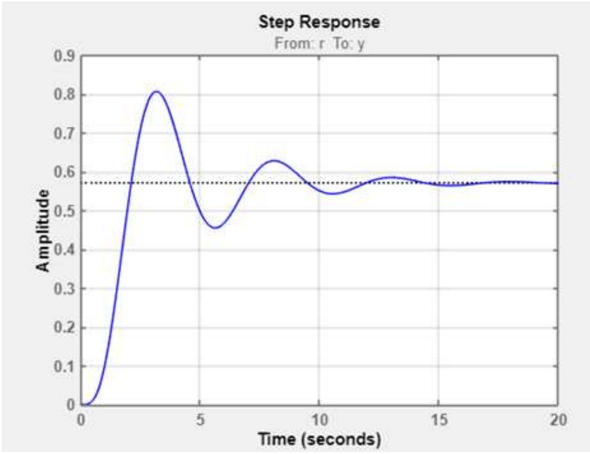

Figure M.8: Step response

The observed time response is too wild (too much overshoot and too many oscillations), and does not reach the desired set value of 1.

1. In what direction (higher or lower) should the control engineer adjust the value of the gain K of the proportional-only controller to obtain a smoother response with less overshoot? What other effects does this have? Explain your answer.
2. What should the control engineer modify in the controller to remove the steady state error (reduce to zero)? Explain your answer.