L TEST EXAM TWO

Introduction & Instructions

This is the resit exam of BCS 2024 FALL.

- Duration: 3 **hours**
- Number of problems: 7
- 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.

Problem 1 (15 points)

Given the block diagram in Fig. L.1.

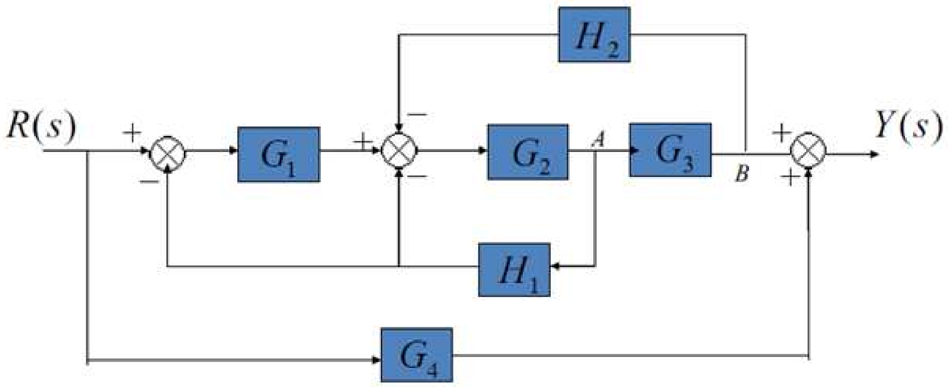


Figure L.1: Block diagram

Find the transfer function:

$$H(s) = \frac{Y(s)}{R(s)}.$$

Show at least two intermediate steps used to find the solution.

Problem 2 (10 points)

Given the following transfer function H(s).

$$H(s) = \frac{200(s+20)}{s(2s+1)(s+40)}$$

Sketch the Bode plots of H(s), including both magnitude plot and phase plot.
Please clearly indicate the asymptotes.
Sketch the Bode plots on the corresponding sketch sheet and remember to also submit the sketch sheets!
Explain how you obtained your sketch (show intermediate steps like asymptotes, how you find cornor frequencies, etc.) on your answer sheet.

Sketch sheet problem 2

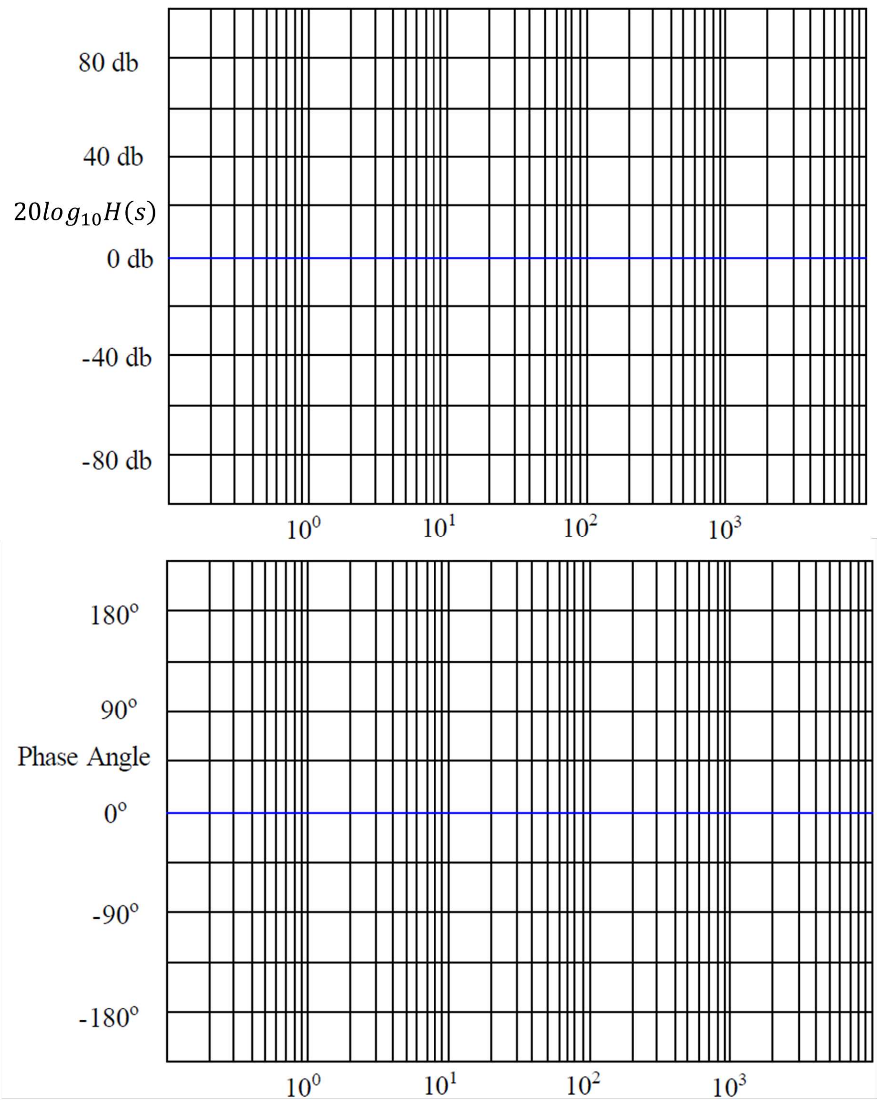


Figure L.2: Bode plots sketch sheet

Problem 3 (21 points)

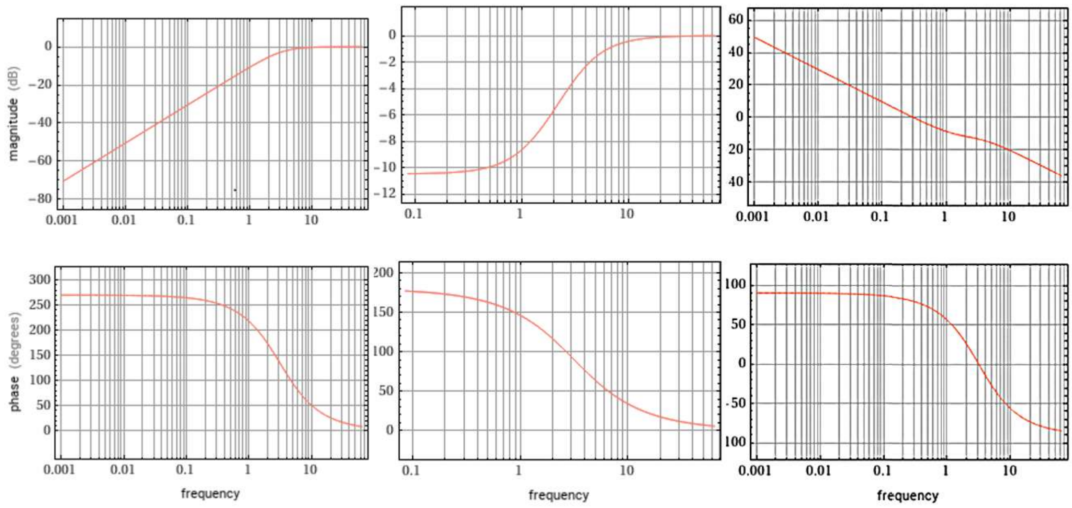
Given the following ordinary differential equation:

$$\frac{d^3y}{dt^3} + 6\frac{d^2y}{dt^2} + 10\frac{dy}{dt} = \frac{d^2x(t)}{dx^2} - 3x(t)$$

Assume ZERO initial condition. Find the solutions to the following qustions:

1. Determine the transfer function $H(s) = \frac{Y(s)}{X(s)}$.
2. Determine the poles and zeros of $H(s)$.
3. Visualize the poles and zeros in the complex plane.

Given the following bode plots in Fig. L.3.



1 2 3

Figure L.3: The 3 candidate Bode plots

4. Out of the plots 1, 2, and 3, which one represents the transfer function derived from the ordinary differential equation? Why?
5. How large is the gain margin of this system?

Problem 4 (10 points)

Determine the transfer function $H_P(s)$ and its parameters K_P, τ_P and τ_ν from the following step response graph in Fig. L.4.

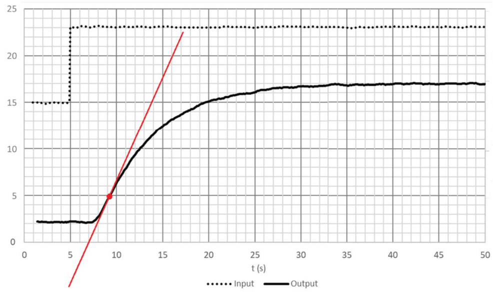


Figure L.4: The step response data

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

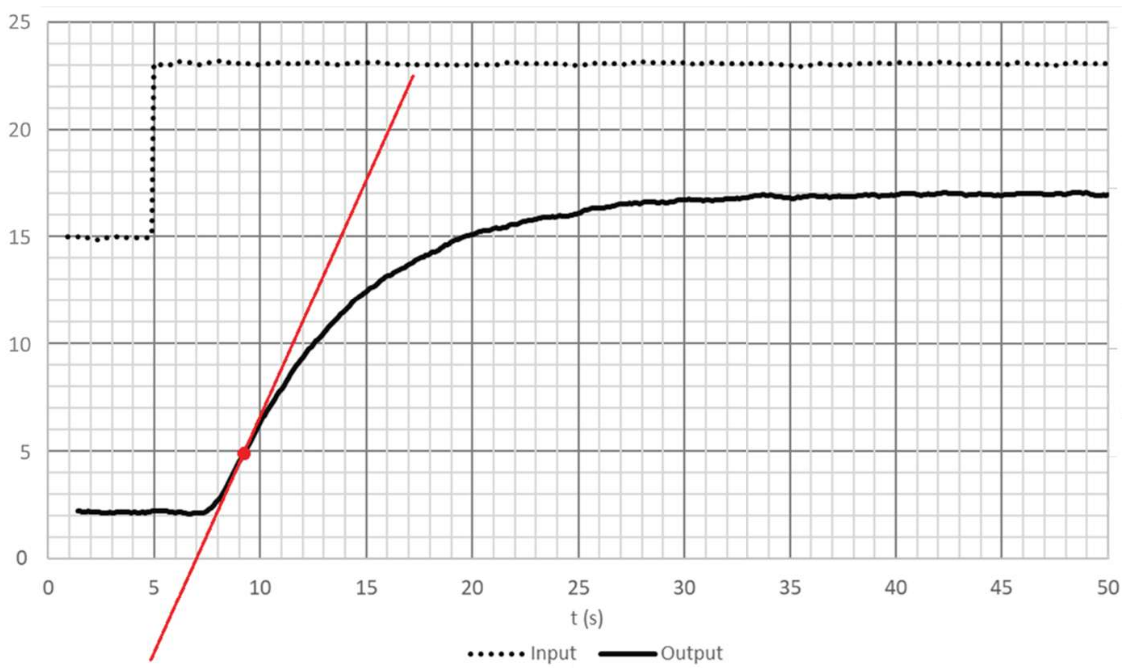


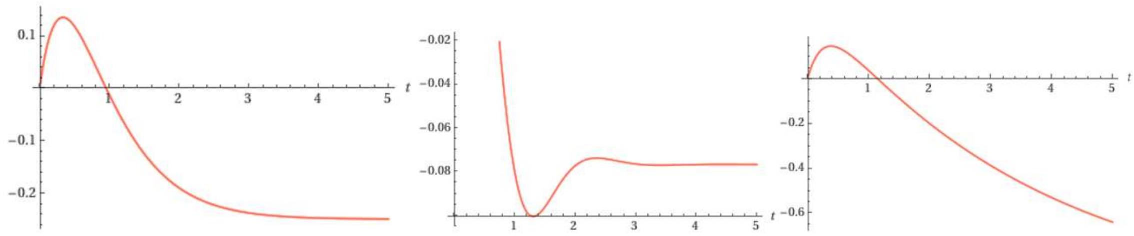
Figure L.5: The step response data

Problem 5 (24 points)

There are 3 systems $H(s)$, $G(s)$, $M(s)$ with their transfer functions given below:

$$H(s) = \frac{s-1}{s^2+4s+1} \quad G(s) = \frac{s-1}{s^2+4s+4} \quad M(s) = \frac{s-1}{s^2+4s+8}$$

There are 3 step response graphs available in Fig. L.6 but we do not know which graph correspond to which system. Find the solutions to the following questions:



1 2 3

Figure L.6: The 3 step response candidates

1. FInd the poles and zeros of $H(s)$, $G(s)$, $M(s)$.
2. Sketch the root locus plots for $H(s)$, $G(s)$, $M(s)$.
3. FInd the time domain function $h(t)$, $g(t)$, $m(t)$.
4. Match the step response graphs with the systems H, G, M. Motivate your selections.

Problem 6 (12 points)

There is an open-loop process with a transfer function $H(s)$ that have 5 poles:

$$s = 2 \quad s = -2 \quad s = -3.8063 \quad s = -0.0968 + 0.503\mathbf{j} \quad s = -0.0968 - 0.503\mathbf{j}$$

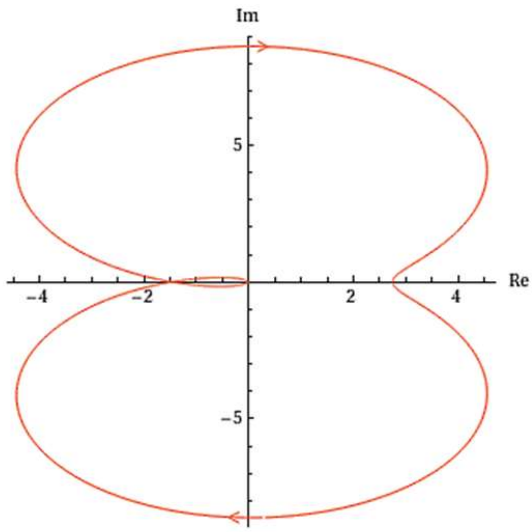


Figure L.7: The Nyquist plot for the transfer function $H(s)$.

Fig. L.7 demonstrates the Nyquist plot of $H(s)$. Assuming a proportional controller K deployed to control the open-loop process with unity negative feedback loop in the closed loop system. Find the solutions to the following problem:

1. Determine the stability of the closed-loop system using Nyquist stability criteria.

There is another open-loop process with a transfer function $G(s)$ that have 2 poles:

$$s = -3.73205 \quad s = -0.267949$$

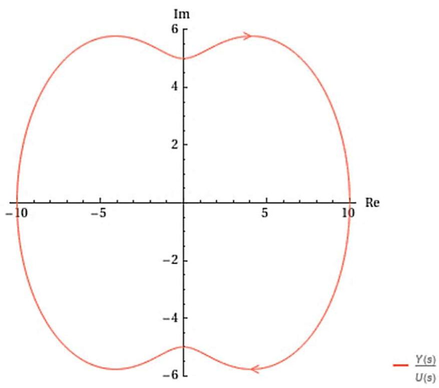


Figure L.8: The Nyquist plot for the transfer function $G(s)$.

Fig. L.8 demonstrates the Nyquist plot of $G(s)$. Assuming a proportional controller K deployed to control the open-loop process with unity negative feedback loop in the closed loop system. Find the solutions to the following problem:

2. Determine the stability of the closed-loop system using Nyquist stability criteria.

3. What if we add an additional proportional controller $K = \frac{1}{50}$ in the unity negative feedback loop, determine the stability using the Nyquist stability criteria.

Problem 7 (8 points)

Consider a PID controller with the parallel structure. Answer the following questions and motivate your answer in **less than 2 sentences** for each question:

1. State one reason why we can never use the D controller alone.

2. Which controller eliminates the steady state error?

3. Will higher gain of the I controller give you higher overshoot when P and D remains the same?

4. I'm using one of the P,I, and D controller to control a process. The step response of the controlled process is plotted in Fig. L.9. Which controller am I using?

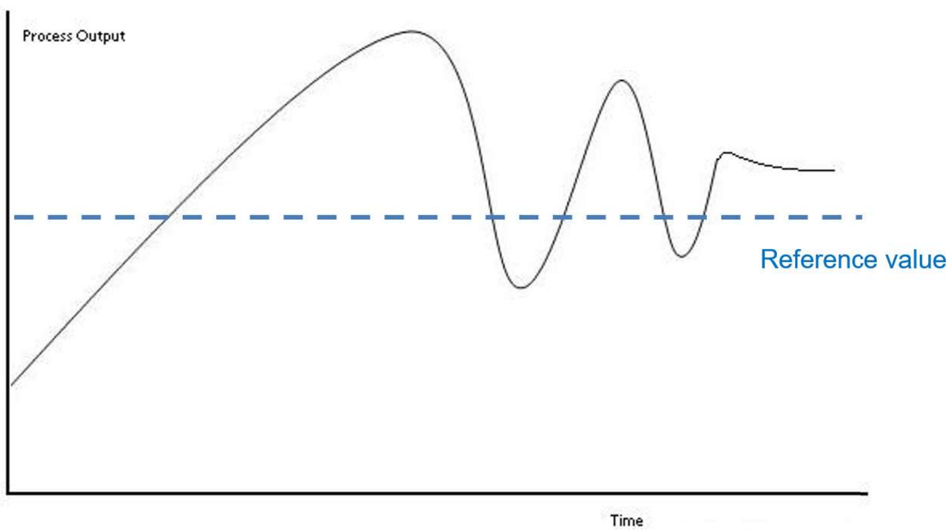


Figure L.9: Step response of the controlled process.