EE4150-S-2024 Control Systems Lab-Exp 1

Time domain and frequency domain analysis of a second order system

Objective:

To perform the time domain and frequency domain analysis of a second order mechanical system.

Software required: MATLAB editor.

Expectations:

- Before coming to the lab-session, read the material presented below and go through related textbooks.
- Write a brief report about your design with the diagrams/plots, results obtained/noted and inferences, if any. Indicate your answers in observation tables wherever necessary.
- Submit the report along with the simulation files. MATLAB uploaded files should be error free. There will be a penalty for erroneous code.
- Report should be written clearly and briefly.
- Ensure the following are presented in your report:
  - Name and Roll Number.
  - Appropriate graphical representation.
  - Obtained parameters.
  - Results and inferences.
- Avoid copying, it will attract zero marks. We encourage discussions, of course. In case you need any clarifications, please contact:

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Problem 1

1. Consider the following spring-mass-damper system (Fig 1) with parameters $m = 1$kg, Spring constant, k=1N/m. The damping coefficient b is a variable parameter. F is the external applied force and x the displacement.

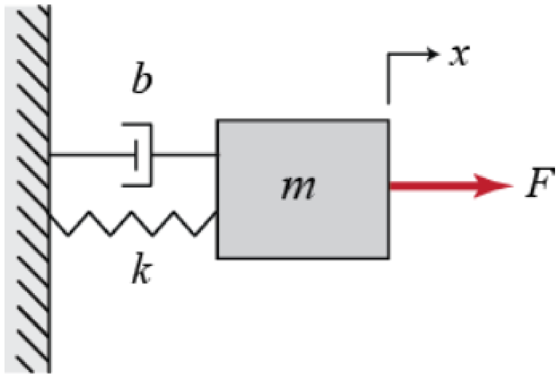

Figure 1: Spring mass damper system

1. Derive the transfer function model of the given mechanical system.
2. Find the value of damping coefficient b such that the system is underdamped. Plot the pole locations on Matlab editor and comment on the stability. What is the value of the damping ratio with the choice of b?

Problem 2

Choose damping coefficient, b=4 Ns/m.

1. Determine the type of response exhibited by the system in MATLAB under unit step, unit ramp and unit impulse excitation. Plot the system responses.
2. Determine the steady-state error of the system subjected to these inputs using simulation and tabulate the results in Table 1.
3. Comment on the steady state error of the system subject to unit ramp input, if a second damper element is added in series/parallel to the existing damper.
4. If the damping coefficient, b of the dashpot is zero, what will be the nature of the system when subjected to unit step input? Plot the response.

Table 1: Steady state error

Type of input	**Steady state error**
Unit step	
Unit ramp	
Unit impulse	

Problem 3

1. (**Time response**)

   (a) Obtain the unit step response of the mechanical system in Fig.1, by choosing damping coefficient b such that the system is underdamped. Compute the time domain parameters manually and in the MATLAB editor. Tabulate the results in Table 2 and 3 respectively.

2. (**Frequency response**) Choose the value of damping coefficient, b such that the system exhibits underdamped, critically damped and overdamped responses.

Table 2: Manual calculation

b (Ns/m)	Type of response	Damping ratio	Settling time	Rise time	Delay time	Time constant	Natural frequency	% Overshoot
	Underdamped							

Table 3: Simulation results

b (Ns/m)	Type of response	Settling time (s)	Rise time (s)	Delay time (s)	% Overshoot
	Underdamped				

(a) Plot the Bode and Nyquist diagrams.

(b) Analyze the stability of the system using Bode and Nyquist plot and tabulate the results in Table-4.

(c) Show the frequency response parameters (Gain margin, phase margin, Gain crossover frequency, phase crossover frequency) on the Bode plot. Compute resonance peak, bandwidth, and resonance frequency manually and write in Table-5.

(d) Comment on the stability of a system with infinite gain margin and -180 phase margin. Justify your answer.

(e) Suppose that the system has a dead time. Comment on the relative stability of the system.

Table 4: (Stability analysis)

b (Ns/m)	Type of response	Comments on stability (Bode plot)	Comments on stability (Nyquist plot)
	Critically damped		
	Underdamped		
	Overdamped		

Table 5

b (Ns/m)	Type of response	GM	PM	ω_{gc}	ω_{pc}	Bandwidth	Resonance peak	Resonant frequency
	Underdamped							
	Critically damped							
	Overdamped							