ME 417 - Num Assignment #1

Control of Mechanical Systems - Fall 2020

Num Assignment Due: Tue, 22 Dec 2020 23:59

Complete the following problems and submit your work as a working notebook and a saved pdf copy. *You can complete the numerical assignment using **Julia**, **Python** or **MATLAB**, and submit your work as a Jupyter Notebook (or MATLAB Livescript) + a pdf export*

Provide response plots as relevant, ensure that you label the figures, the axes, title plots and legends. Any controller design specifications given, should be met by observing the time response of the system. The Numerical Lessons provided will aid greatly in carrying out this assignment.

Collaboration is only allowed within the group members.

Problem 1

Linear System Response (30pts)

Given the following transfer function

$$G(s) = \frac{100.0v\,(s+4.0)}{s^2 + 100.0v\,(s+4.0) + 108.0}$$

a. (40%) Simulate the step response of the system for the following values of $v = \begin{bmatrix} 0.1 & 1.0 & 3.0 & 8.0 & 16.0 \end{bmatrix}$. Plot the responses on a single plot.

b. (30%) Discuss the differences observed between the responses with different values of v

c. (30%) Simulate the response of the system to the following inputs, with the choice of $v = 8.0$. Provide three subplots, with each one showing the input and the response. Explain the observed differences between the responses.

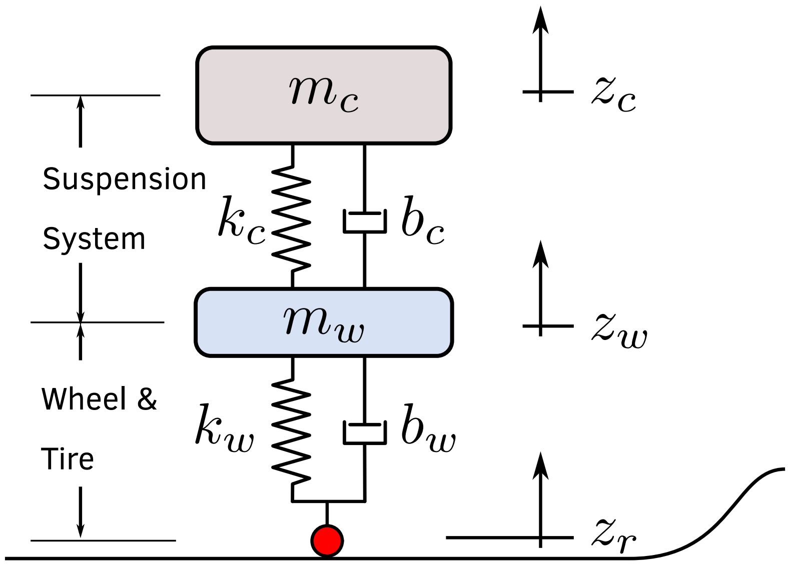
Note that to simulate the response of a transfer function with a zero, you can split the transfer function using partial fraction expansion, simulate the response of each term and recombine the result.

1. $u_1(t) = 2sin(10t)$ for $t = \{0, 5\}$
2. $u_2(t) = 2sin(100t)$ for $t = \{0, 0.5\}$
3. $u_3(t) = 2sin(500t)$ for $t = \{0, 0.05\}$

Problem 2

Multi-DOF Response to a Cyclic Input (35pts)

Given the following car passive quarter suspension model.



With $m_c = 1.0$ Metric Tons, $m_w = 20kg, b_c = 1000N \cdot s/m, b_w = 900N \cdot s/m, k_c = 1500N/m, k_w = 2000N/m$

In this problem, simulate the response using **Basic Numerical Integration**

a. (20%) Derive the equations of motion for the system.

b. (40%) Treating z_r as the input to the system. Simulate the response to a step input $z_r = 0.2$. Plot the response of z_c and z_w in one subplot and $\dot{z}_c$ and $\dot{z}_w$ in another.

c. (20%) If the input is modeled as a sinusoidal function $z_r = 0.2sin(\pi vt)\,m$

Where v is the speed of the car in m/s and t in seconds.

Simulate the response of the system to the following speeds: $v_1 = 10km/h$, $v_2 = 20km/h$, $v_3 = 60km/h$

Plot the response of z_c to the three inputs in one subplot, and the three z_w responses in another.

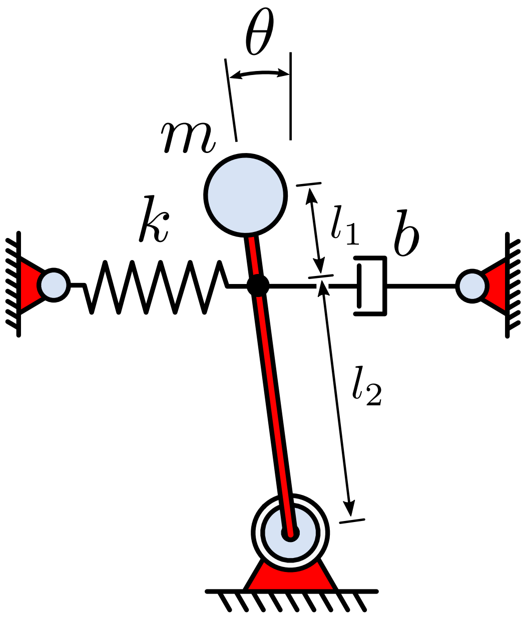
d. (20%) Repeat the simulation with the sinusoidal inputs, but this time ignore the negative components of z_r (Similar to consecutive road bumps)

Use a time sample of $0.001s$ or less in the numerical integration.

Problem 3

Nonlinear vs. Linear System Response (35pts)

Given the following inverted pendulum. Modeled as a point mass of negligible size connected to a massless rod. With a passive mechanical controller.



With $m = 2kg, b = 10N \cdot s/m, k = 70N/s, l_1 = 50.0cm, l_2 = 90.0cm$

a. (30%) Derive the equations of motion of the system.

b. (30%) Using basic numerical integration, simulate the natural response of the system given the initial following condition $\theta = 60^o, \dot{\theta} = 1.8rad/s$

c. (30%) Linearize the system (assume small angle approximation), then derive the transfer function of the system. Define the input as the moment around the pivot. Then simulate the natural response of the system using lsim(), with the above initial conditions.

d. (10%) Discuss the differences observed between the linear and nonlinear response. Why would you want to simulate the nonlinear response of dynamical systems, instead of the linear model?

Assume the spring and damper move horizontally only.