Project #2
MECH 3010: Elementary Numerical Methods and Programming
Spring 2023

DUE Thursday, May 4, 2023

Introduction:

You have been hired by The Rusty Bolt, Inc., a company that designs and fabricates carnival rides. Your first project is to design the oscillating seats for a new ride called the Rockin' Roller (illustrated below). The seats on the Rockin' Roller will be attached to a spring-dashpot system to allow each seat to undergo damped oscillation. During operation of the Rockin' Roller, the seats are pulled forward and then released and allowed to oscillate. You have already selected the spring for the system, and now you must choose one of three different dampers to complete the system. Your goal is to make the ride fun (by allowing several oscillations to occur in a given time span) but not too dangerous (by limiting the maximum speed achieved by the seat).

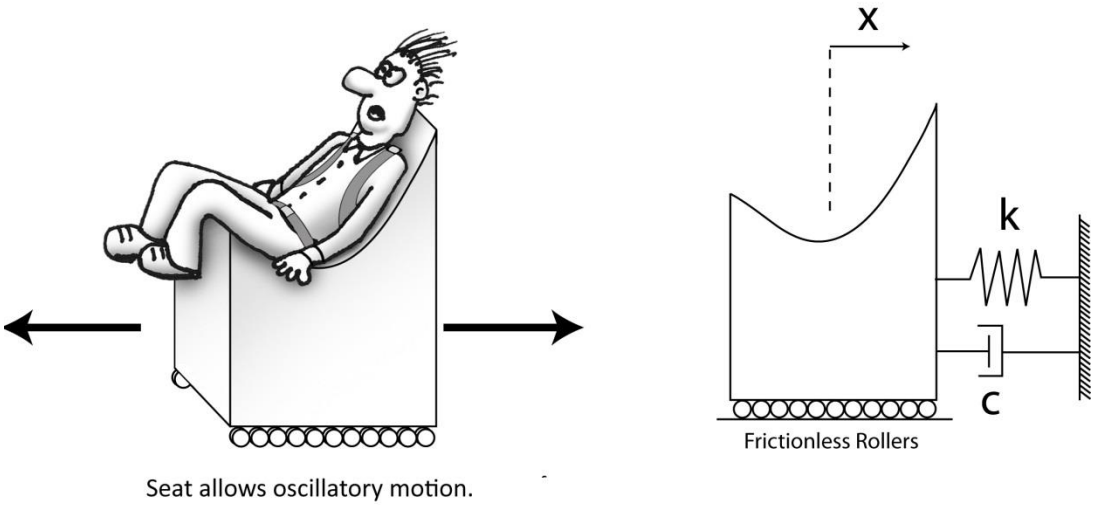

Figure 1. Artist's rendition of the oscillating seat of the Rockin' Roller (left), and idealized engineering model of the system indicating the seat position (x, measured from the resting position of the system), spring constant (k), and damping coefficient (c). The rollers at the bottom of the seat can be considered frictionless for the analysis.

Known Information:

Spring and damper testing results:

The spring and three different dampers have been tested to help determine the spring constant (k) and the damping coefficients (c_1, c_2, and c_3). For springs, force (F) is proportional to spring displacement (d, the distance the spring is stretched or compressed) according to the relationship F = kd. The file called KData.txt contains a set of data with displacement (units of meters) in the left column and force (units of Newtons) in the right column. For dampers, force is proportional to velocity (v) of damper shortening or lengthening according to the relationship F = cv. The files called C1Data.txt, C2Data.txt, and C3Data.txt each contain testing data for a single damper. The left column contains velocity measurements (units of meters per second), and the right column contains force measurements (units of Newtons). The four data files are available on Canvas.

Mass of the seat and rider:
The shape of the seat is defined by a function f(s) over the interval $0.05 \le s \le 0.75$. The seat has a width (w) of 0.5 m and is made of a polymer foam with a density (ρ) of 100 kg/m^3. The mass of the seat (m_{seat}, units of kg) can be determined by computing this integral:

$$m_{seat} = \rho w \int_{0.05}^{0.75} \left(3s^2 \cos\left(\frac{1.2}{\sqrt{s}} \right) + 0.7 \right) ds$$

You may assume an average rider mass (m_{rider}) of 75 kg. The total mass of the seat and rider can then be determined as $m = m_{seat} + m_{rider}$.

Motion of the seat:
The system follows the standard equation of motion for a damped mass-spring system, where x (units of meters) is measured from the resting position (x = 0) of the system:

$$m\frac{d^2x}{dt^2} + c\frac{dx}{dt} + kx = 0$$

where m = combined mass of the rider and seat (kg), c = damping coefficient (N·s/m), k = spring constant (N/m), and t = time (s).

Instructions:
You must write a MATLAB program that automatically performs all the necessary calculations to solve for the motion of the system using each of the three different dampers for the time span $0 \le t \le 5$s, where x(0) = -1 m and v(0) = 0 m/s. You must then use the results to select the damper that will be used in the Rockin' Roller. To reach this goal, you must perform the following tasks:

1. Load the KData.txt, C1Data.txt, C2Data.txt, and C3Data.txt files, which contain the testing data for the spring and the three dampers.

2. Based on the testing data for the spring and dampers, use linear regression to determine the spring constant (k) and the three different damping coefficients (c_1, c_2, and c_3).

3. Generate plots of the testing data for the spring and dampers that include the individual data points and the linear regression models.

4. Use numerical integration to compute the mass of a Rockin' Roller seat.

5. Numerically solve for the motion of the system over the time span $0 \le t \le 5$s, given the initial conditions x(0) = -1 m and v(0) = 0 m/s. Solve for the motion using each of the three different dampers.

6. Plot the seat location (x) and seat velocity (v) over the 5-second time span when using each of the three different dampers.

7. Select the damper you will use for the Rockin' Roller. In order to make the ride fun, the seat should cross the equilibrium position (x = 0) at least three times during the 5-second time span. In order to make the ride safe, the magnitude of the seat velocity should not exceed 1.5 m/s at any time.

Project Report: Turn in a typed report containing the following:

1. Title page (1 point)
    - Include your name and a brief, descriptive title for the project.

2. Introduction and objectives (5 points):
    - Write a paragraph introducing the project and stating the objectives you will achieve.

3. Program description (10 points):
    - Describe the program you wrote and how you achieved each of the items 1-6 in the instructions. Specifically state the numerical methods you used, and briefly describe how they work.

4. Plots of testing data along with linear regression models (12 points)
    - Include plots (with appropriately labeled axes and legends) of the individual data points for the tests of the spring and the three dampers along with the linear regression models used to determine k, c_1, c_2, and c_3.

5. Values of k, c_1, c_2, and c_3 (4 points).
    - List the values (with correct units) you found for the spring constant and three damping coefficients.

6. Mass of a Rockin' Roller seat (3 points)
    - List the mass of the seat (with correct units).

7. Plots of seat location (x) and seat velocity (v) over the 5-second time span (20 points)
    - Plot the seat location (x) over the 5-second time span. Include plots for all three dampers in a single figure with appropriately labeled axes and a legend.
    - Plot the seat velocity (v) over the 5-second time span. Include plots for all three dampers in a single figure with appropriately labeled axes and a legend.

8. State which damper you will use in the Rockin' Roller and why. (5 points)

9. Printout of code (10 points).
    - Include all MATLAB m-files (including any code you obtained from the textbook) used to complete the project.