**Lab #1 - Free Vibration Name:**

**Short Form Report Date:**

 **Section / Group:**

*Procedure Steps (from lab manual):*

1. *Follow the Start-Up Procedure in the laboratory manual. Note the safety rules.*
2. *Locate the various springs and masses for the mass-spring-dashpot experimental system.*

Part I. Displacement Experiment A

1. *Disconnect the damper by unhooking the damper rod from the mass.*

Fill out the table below and print the 3 responses, labeling them “Figure 1.A1”, Figure 1.A2”, and “Figure 1.A3” for the following three cases:

 Line 1: 1 mass, weakest spring

 Line 2: 1 mass, stiffest spring

 Line 3: All 4 masses, stiffest spring

 For the table below, refer to the manual for the actual mass and spring constants.

Table 1. Data Sheet for Part I, Questions 1 and 2

|  |  |  |  |
| --- | --- | --- | --- |
| Mass (*kg*) | Spring Constant (*N/m*) | Experimental Natural Frequency, *n* (*rad/sec*) | Theoretical Natural Frequency, *n* (*rad/sec*) |
|  |  |  |  |
|  |  |  |  |
|  |  |  |  |

1. (5%) Find the experimental frequency of oscillation for each of the three cases. Show a sample calculation below.

2. (5%) Find the associated theoretical natural frequency for each of the three cases and compare the results to the experimental data. Are they close? Why might they be different?

3. (10%) A system with natural frequency  has its mass doubled, producing a system with natural frequency . The original system has its spring stiffness tripled, producing a system with natural frequency . What is the numerical value of the ratio 

4. With the damper still disconnected, observe the response of the system.

a. (5%) Identify the effect(s) that cause the system to stop vibrating.

b. (5%) Describe a method for determining if the system is *viscously* damped.

Part I. Displacement Experiments B&C

1. *Re-connect the damper and keep the stiffest spring and all 4 slotted weights.*
2. *Start with the dashpot in the completely tightened position*

You will now run an experiment to view the transition from an over damped response to an under damped response. You are not required to make copies of each of the responses, but will be submitting one example of each type with the following labels:

 Label the over damped case “Figure 1.B1”.

 Label the critically damped case “Figure 1.B2”.

 Label the under damped case “Figure 1.B3”.

As you run the experiment take note of shape of the response as the damping is reduced.

Vary the damping by turning the thumbscrew on the dashpot. This will give an over damped system response (no oscillations). Check this by observing the system's displacement on the monitor. Subsequent cases should be viewed having opened the thumbscrew 1/6 turns after each trial, until 3 full turns have been completed (approximately 18 trials.) Compare the form of the time histories you get at each setting with those depicted in Figure 1.3 of the lab manual.

5. For the same mass and spring combination used above, obtain a plot of the underdamped response associated with the thumbscrew opened approximately 3 turns. Try and have at least 5 oscillations visible on your plot. Print and attach the plot labeling it “Figure 1.C1”. Collect data from the file and fill in Table 2. Use these data to answer parts (a) through (c).

Table 2. Log Decrement Data Sheet

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | *s*=0 | *s*=1 | *s*=2 | *s*=3 | *s*=4 | *s*=5 |
| Displ.  (cm) |  |  |  |  |  |  |
|  |  |  |  |  |  |  |

1. (5%) Compute the log decrement ** and the damping ratio  using  and .

b. (10%) Determine the damping ratio by using an exponential curve fit in Excel. First, enter the time and amplitude for each of the successive peaks into an excel spreadsheet. Then, plot it, making sure that it matches the displacement plot from the monitor. Then, right click on a data point and add trendline. From that, pick the exponential curve fit. Then, right click on the trendline, go to options, and “display equation on chart”. From the equation, compare it to the sinusoidal amplitude response that we would expect from a damped resonator. Use the experimental natural frequency. Write the exponential equation obtained and also your damping ratio. (You may do this in Matlab if you know how; hint: >>fit(T,Y,’exp1’) ).

c. (5%) Discuss the advantages and disadvantages of each method, and compare the values of the damping ratios obtained in part (a) and (b). Which is the more accurate and why?

1. (2%) “Figure 1.C1” is measured in cm. If we had instead measured in inches, would it affect your answer to part (a) & (b)? Why or why not?

6. (8%) Measure  from the time trace used to answer question 5. Compare this value with the calculated value of  where  is the value found in question 5 and  is the corresponding theoretical value. (Note that the system has a different mass since the damper is now attached.)

7. (8%) A system with damping ratio  has its spring rate doubled, producing a system with damping ratio . The original system has its mass tripled, producing a system with damping ratio . Find the numerical value for the ratio 

Part II. Forces Experiment C

1. *Keep the 4 masses and stiffest spring on the experimental system.*
2. *Using your data from Experiment I.C, run the Matlab program Lab1Forces.m. The program requires you to enter the correct values for mass, stiffness, and the damping ratio (that you calculated using the logarithmic decrement method) that are associated with the actual system you are testing (hint: they should be close to the default values).*

Print a copy of the “Force” graph and label it Figure 1.C2.

8. (5%) The “Force” graph displays three force functions: $x\left(t\right), c\dot{x}\left(t\right),$ and $kx\left(t\right)+c\dot{x}(t)$. Indicate on your printed copy of the time traces which is $kx\left(t\right)$, which is $c\dot{x}\left(t\right)$ and which is the combined force function $kx\left(t\right)+c\dot{x}(t)$. Explain the reasoning behind your choice.

9. (5%) Based on the recorded function $x(t)$, the measured natural frequency, and the damping coefficient, estimate what the spring force and the damping force should be. Are these in close agreement to the plots you obtained for question (1) above?

10. (7%) Can the maximum transmitted force be calculated by adding the maximum spring force plus the maximum damper force? (e.g., say max(*Fs*)=9 and max(*Fd*)=3, is the max(Total)=12?). Why/why not?

Part III. Phase Plane Experiment D

1. *Use the Matlab program “Lab1PhasePlane.m” to plot data in ‘Phase Space’.*

Displace the mass by $x\left(0\right)=3cm$ and release the system from rest, $\dot{x}\left(0\right)=0.$ Save the data as “Lab1Data1.m” and run “Lab1PhasePlane.m” in Matlab. Make a printout of this graph and label it “Figure 1.D1”. Plots such as these that show velocity versus displacement are known as phase-plane or state-space plots.

1. (5%) As time increases, the curves in general will trace out a spiral. Indicate the direction of increasing time. Explain why you have shown this direction.

2. (5%) Increase the damping by turning the thumb screw three full turns. Repeat the experiment and label the figure “Figure 1.D2”. Explain your observations in terms of the increase in damping.

3. (5%) Theoretically, what would the phase plane look like if there were zero damping in the system. i.e., no loss of energy as the system vibrates? Mark the direction of increasing time and the relationship between the max. displacement and the max. velocity.

Part IV. General

1. (5%) In a short paragraph, discuss some possible applications of how the material covered in this laboratory could be used in a real application.