# LAB 1: FREE VIBRATION

## 1.1. **Start-Up Procedure.**

1.1.1. *The Physical Setup*
The experimental apparatus has three carts. This experiment will focus on the center cart. For your initial setup, be sure that you have found the tools required: 4 masses (500±5 grams each), 3 springs (nominally: 175 N/m, 400 N/m, 800 N/m), and hex wrenches. Each cart weights about 700 grams. Additionally, check the apparatus to be sure it is in the following configuration:

(1) The stops for cart 1 and 3 are set to render the carts immobile.
(2) Cart 2 has a single 500g mass on it.
(3) The weakest spring is connecting carts 2 & 3. No spring is connecting carts 1 & 2.
(4) The damper is connected to cart 2.

1.1.2. *Safety Items.*

(1) Do not touch the device while it is moving.
(2) Before touching the apparatus, use a pencil to move the 1st mass to verify that the system is not being actively controlled.
(3) Make sure the carts can move without obstruction.
(4) Make sure that the masses are held tight by the screw.
(5) When connecting dashpot take care to not over-tighten or cross thread the screws.

1.1.3. *Exporting Data and Printing Plots.*

(1) **Data Export**: (Data → Export Raw Data). Save the file in the same directory as the Matlab codes for the lab.
(2) **Print Plot**: (Plotting → Setup Plot). Put the Encoder 2 position on the left axis. Leave the right axis empty. (Plotting → Print Plot). You may physically print the plot OR use snip to capture the screen.

1.1.4. *Turn on the power.*

(1) Download the Matlab programs for Lab 1 from the course website. Be sure to include "Lab0GetData.m" in your folder as well.
(2) Open the ECP32 program located at start → Programs → ecp → ecp32
(3) Turn on the ECP system by pressing the black "ON" power button on the white and black box.

1.1.5. *Helpful Hints.*

(1) Be sure to fill out the "Short Form Report" as you procede through the lab. DO NOT WAIT UNTIL THE END!
(2) Reset the zero if the plot has an offset (Utility → Zero Position )

# Part I. Displacement

1.2. **Experiment A.** - Free oscillations of a spring-mass system

*Goals:* The goal of this experiment is to determine the mass of the cart and compare the experimental and theoretical natural frequencies.

(1) Disconnect the damper from the cart and make sure it will not interfere with the movement of the cart.
(2) Make sure that the position units are in centimeter units. (Setup → User Units → Centimeters)
(3) We will now do a free vibration experiment where you set the initial conditions by hand, and then let the system evolve. You will record the response with the ECP software and export a plot and data.
   (a) Zero the position (Utility → Zero Position).
   (b) ( Command → Trajectory → Sinusoidal → Open Loop Move) and 0V for amplitude. Then, put the frequency at 1Hz and the reps at 10, press OK, that will give a time trace of 10 seconds which should be long enough to capture the response.
   (c) Now, displace the cart by 2-3 cm and hold it there. Go to (Command → Execute) with the normal sampling. Right after you press (Run), let go of the cart. The data will be recorded by the ECP program.
   (d) Then, **Plot** the data (see Startup 1.1.3-2). Label the plot "Figure 1.A1".
(4) Remove the spring between carts 2 and 3. Replace it with the stiffest spring. Repeat step (3), but label the plot "Figure 1.A2"
(5) Add the 3 remaining masses to the cart. Repeat step (3), but label the plot "Figure 1.A3"

1.3. **Experiment B.** - Free Oscillations of a spring-mass-*damper* system

*Goals:* The goal of this experiment is to observe the transition from an overdamped reponse to an underdamped response.

(1) Re-connect the damper to cart 2. Mass 2 should still have 4 weights and the stiffest spring.
(2) We will now do a free vibration experiment where you set the initial conditions by hand, and then let the system evolve. Before we record the data lets look for the transition. When you find it, note the position of the thumbscrew.
   (a) Turn on constant plotting. (Plotting → Real Time Plot). You may need to adjust the axis (Plotting → Axis Scaling).
   (b) Turn the thumb-screw on the dashpot until it is tight, but not too tight. (clockwise turns).
   (c) Displace the mass by 2-3 cm and hold it there for 3 seconds. Release the mass and observe the motion.
   (d) Note whether the system is over, under, or critically damped.
   (e) Turn the thumb-screw 1/6 turn counter-clockwise.
   (f) Repeat steps (c)-(e) until you've turned the thumbscrew about 3 full rotations. You should turn until you can see at least 6 oscillations on the plot. Make a note of the screw position.
(3) Now adjust the thumb-screw to the point where the system transitions from underdamped to overdamped. You may have to repeat step (2c) a few times to find the right spot.
(4) We will now get three plots. One of each type of motion. Underdamped, critically damped, and overdamped. You will record the response with the ECP software and export a plot and data.

(a) Set ( Command → Trajectory → Sinusoidal → Open Loop Move) and 0V for amplitude. Then, put the frequency at 1Hz and the reps at 10, press OK, that will give a time trace of 10 seconds which should be long enough to capture the response.
(b) Now, displace the cart by 2-3 cm and hold it there. Go to (Command → Execute) with the normal sampling. Right after you press (Run), let go of the cart. The data will be recorded by the ECP program.
(c) Then, **Plot** the data (see Startup 1.1.3-2). Label the plot "Figure 1.B2-critically damped.".

(5) Turn the thumb-screw clockwise (tighten) about 1/4 turn and repeat step (5). Label the plot. "Figure 1.B1-over damped".
(6) Turn the thumb-screw counter clockwise (loosen) about 1/2 turn and repeat step (5). Label the plot. "Figure 1.B3-under damped".

1.4. **Experiment C.** - Free Oscillations of a spring-mass-*damper* system.
*Goals:* The goal of this experiment is to compute the damping coefficient for an underdamped system.

(1) Without changing the setup from Experiment B, turn your screw back to where 6 oscillations were visible (approx. 3 turns from closed) and record the behavior.
  (a) Set ( Command → Trajectory → Sinusoidal → Open Loop Move) and 0V for amplitude. Then, put the frequency at 1Hz and the reps at 10, press OK, that will give a time trace of 10 seconds which should be long enough to capture the response.
  (b) Now, displace the cart by 2-3 cm and hold it there. Go to (Command → Execute) with the normal sampling. Right after you press (Run), let go of the cart. The data will be recorded by the ECP program.
  (c) Then, **Plot** the data (see Startup 1.1.3-2). Label the plot "Figure 1.C1".
  (d) **Export** the data (see Startup 1.1.3-1) to the directory with your Matlab files. Label the exported data "Lab1C1.m".
(2) Open Matlab, navigate to the folder with your files, and run "Lab1Displacement.m".
(3) Use the Data Cursor to find the position at each peak.

# Part II. Forces

1.5. **Experiment C.** - Continued.
*Goals:* The goal of this experiment is to calculate the the spring and damping forces present in experiment C.

(1) Go to Matlab and run program "Lab1Forces.m".
(2) Enter the appropriate values for system mass, spring constant, and damping coefficient (as computed for shortform answer 5a). *Be sure to use the correct units!*
(3) **Print** the Matlab Plot and label it "Figure 1.C2".

# Part III. Phase Plane

1.6. **Experiment D.** - Single degree of freedom phase space.

*Goals:* The goal of this experiment is to plot and interprete motion in phase space or state space.

(1) Be sure your experimental setup has not changed from the end of Experiment C.
(2) We will now do a free vibration experiment where you set the initial conditions by hand, and then let the system evolve. Data will be extracted and plotted in Matlab.
   (a) Set ( Command → Trajectory → Sinusoidal → Open Loop Move) and 0V for amplitude. Then, put the frequency at 1Hz and the reps at 20, press OK, that will give a time trace of 20 seconds which should be long enough to capture the response.
   (b) Now, displace the cart by 2-3 cm and hold it there. Go to (Command → Execute) with the normal sampling. Right after you press (Run), let go of the cart. The data will be recorded by the ECP program.
   (c) Then, **Export** the data (see Startup 1.1.3-1) to your folder with the Matlab files. Label the Data "Lab1D1.m".
   (d) Go to Matlab and run the program "Lab1PhasePlane.m". Plot the resulting figure and label it "Figure 1.D1".
(3) Turn the thumb-screw on the dashpot clockwise (tighten) about 3 turns. and repeat step (2), labeling the plot as "Figure 1.D2".

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