ME 4501: Vibrations and Control Lab

Lab 2 Instructions

Due: 6/8 for Section 2 and 6/9 for Section 1 by 5 pm

Objectives:

- To measure the natural frequency of several one-degree-of-freedom (DOF) vibration systems using simple experiments and comparing with theory.
- Understand how changing mass or spring constant/stiffness affects the natural frequency.
- To calculate the spring constants from theory using Machine Design equations and compare with given values.
- To obtain the key properties of a single-degree-of-freedom (SOF or 1DOF) freely vibrating system using experiments and theory
- To experimentally determine the damping coefficient and damping ratio of a SDOF system.

Equipment:

Figure 1. Lab 2 equipment list

The equipment required to successfully complete Lab 2 is shown in Figure 1 and listed below:

1. ECP Model 210
2. Scale
3. Accelerometer

4. NI Signal Express
5. Data Acquisition Card
6. Cable
7. Loads
8. Springs

Procedures

A. Spring Constant Calculation

Theory: The main dimensions of a helical spring subjected to compressive force are shown in Figure 2. They are as follows:

k= Spring constant of spring (N/m)

d = wire diameter of spring (m)

Di = inside diameter of spring coil (m)

Do =outside diameter of spring coil (m)

D = mean coil diameter (m)

G= shear modulus (stainless steel), 75 GPa

N_t= number of coils

N_a= efficient number of coils (N-2)

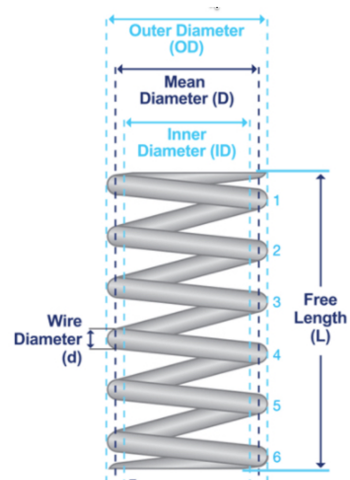

Figure 2. Compression spring

Therefore,

$$D_i = D_0 - 2 \times d \quad \text{(Eq.1)}$$

$$D = \frac{D_0 + D_i}{2} \quad \text{(Eq. 2)}$$

$$k = \frac{d^4 G}{8D^3 N_a} \quad \text{(Eq.3)}$$

1. Measure the diameter of the coils for each spring.
   $(d_{soft} = 1.4\ mm, d_{medium} = 1.6\ mm, d_{stiff} = 2.02\ mm)$
2. Measure the outer or coil diameter of each spring (i.e. the spring diameter).
   $(D_{o_{soft}} = 25.7mm, D_{o_{medium}} = 26.2mm, D_{o_{stiff}} = 26.3mm)$
3. Measure the free length of each spring type
   $(L_{soft} = 102\ mm, L_{medium} = 102mm\ and\ L_{stiff} = 103mm)$
4. Count the total number of coils, N_t, in each spring, including the “squished” coils at the ends.

5. The nominal values of the spring constants are 200 N/m (soft), 400 N/m (medium) and 700 N/m (stiff).
6. Calculate the stiffness of each spring using Eq. 1 by filling the Table 1.
7. Find the difference using the Eq. 4
8. $$\% \, Diff = \frac{K_{nomial} - K_{theoretical}}{\frac{K_{nominal} + K_{theoretical}}{2}} x100 \qquad \text{(Eq.4)}$$

Table 1. Spring Constant Calculation

Spring Type	**N_t**	**N_a**	**d**	**D_o**	**D**	**L**	**K_{th}**	**$K_{nominal}$**	**% Diff**
Soft									
Medium									
Stiff									

B. Free Response Data Collection for System 1, System 2 and System 3

1. Create a SDOF system (*System 1*) arranged with a single cart, thin load, thick load and a medium spring Attach the triaxial accelerometer to the cart as shown in Figure 2. Connect the

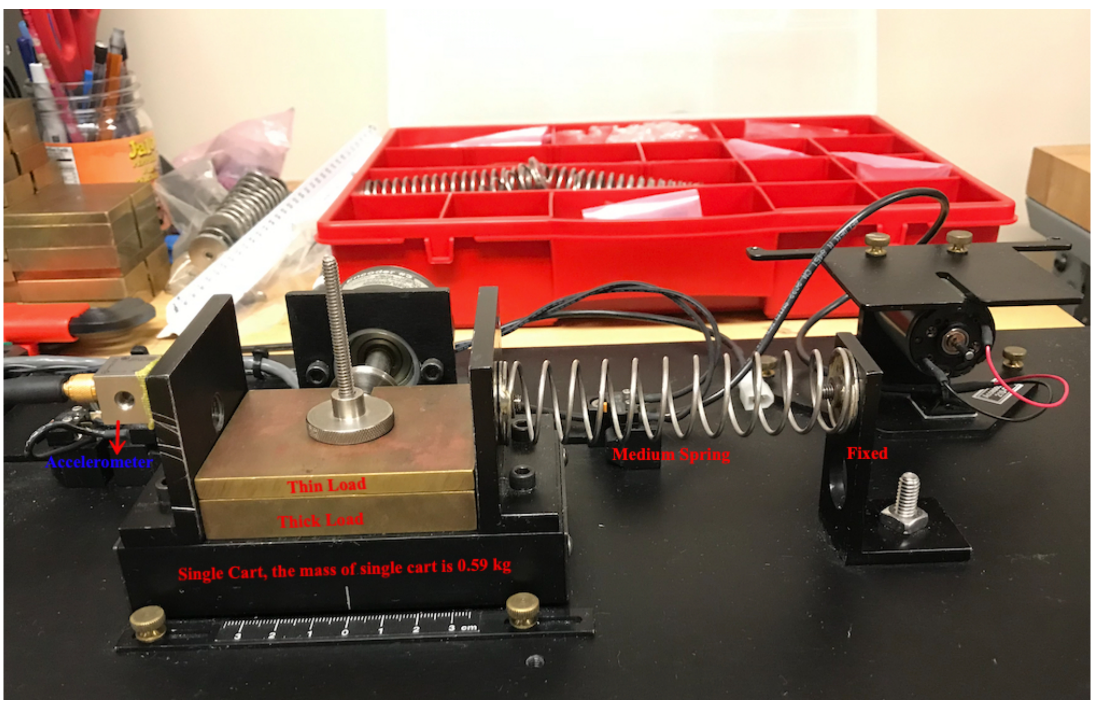

Figure 2. System 1 is consisted of the single cart (0.59 kg), thick load, thin load and a medium spring

accelerometer to the channel 1 on data acquisition card (DAQ). Connect the DAQ to the computer.

The nominal values of the thick and think loads are 0.5 kg and 0.25 kg respectively. The mass of a single cart is 0.59 kg. The nominal value of the medium spring constant is 400 N/m. The actual values are shown in Figure 1.

2. Open NI Signal Express and add acceleration using Channel 1. Set the correct parameters for the accelerometer.
3. Collect free response data by replacing the cart by 2 cm to the left. Record the data in NI Signal Express while releasing the cart. Export System 1 data to an excel file.
4. Create *System 2* by changing the total mass of system 1 as shown in Figure 3 and record free response data by replacing the cart by 2 cm to the left and releasing.
5. Create *System 3* by changing the stiffness of system 2 as shown in Figure 4 and record free response data by replacing the cart by 2 cm to the left and releasing.
6. Watch ***"Lab 2 Recordings"*** from D2L. The video, which is 4 min and 10 seconds long, shows the free response data recordings for System 1, System 2 and System 3

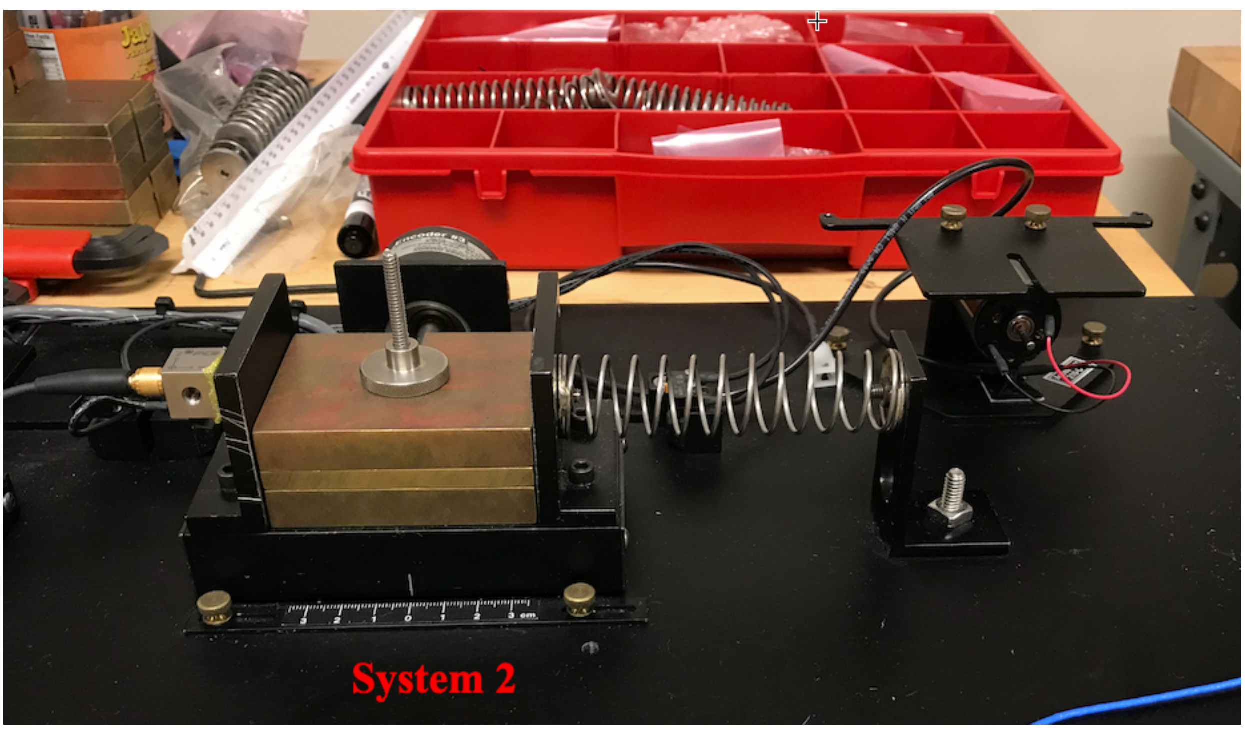

Figure 3. System 2 is consisted of the single cart (0.59 kg), 2 thick loads, 1 thin load and a medium spring

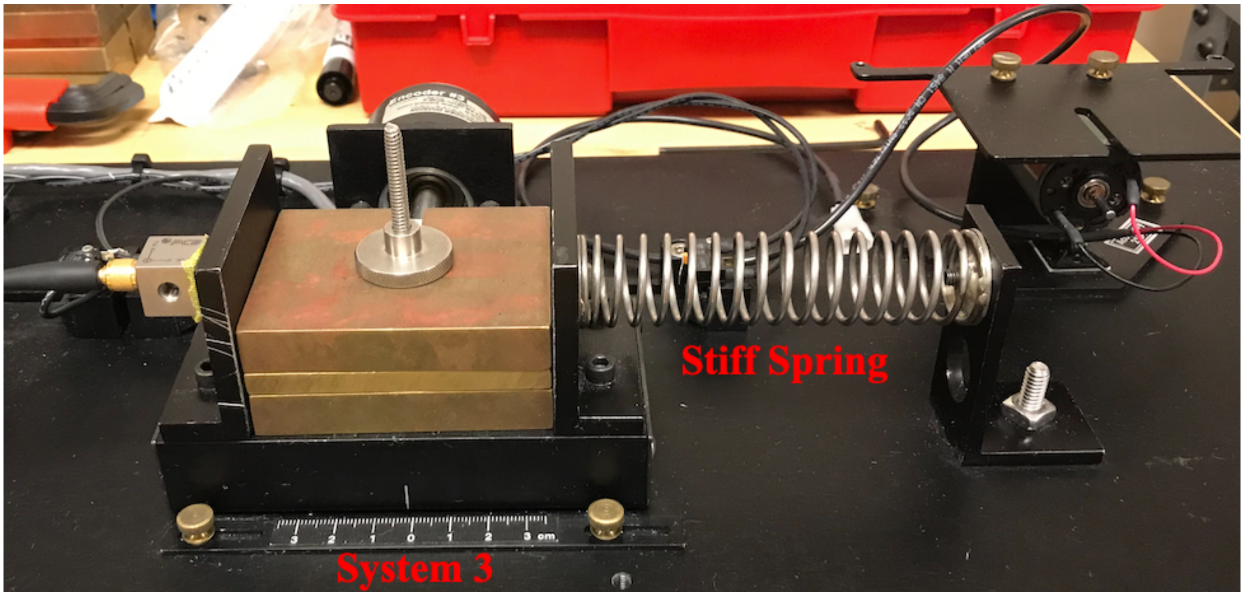

Figure 3. System 3 is consisted of the single cart (0.59 kg), 2 thick loads, 1 thin load and a stiff spring

7. Download ***"Lab 2 data"*** excel file from D2L. The excel file has the time response data for each system.

C. Finding the Natural Frequency of SDOF

1. Download "Lab 2 Notes- Natural Frequency" document from D2L.
2. Watch "Lab 2 Finding Natural Frequency of SDOF" Video from D2L.
3. Watch "Lab 2 Finding Natural Frequency of SDOF from Experimental Data" from D2L.
4. Fill in the blanks in the Table 2 using the calculated values, not the nominal values.

Table 2. Calculation of natural frequency of SDOF System

System	Total mass, M	Stiffness K	$\omega_{n_{theoretical}}$	$f_{n_{theoretical}}$	$f_{n_{experimental}}$	$\omega_{n_{experimental}}$	% Diff
System 1							
System 2							
System 3							

5. Watch "ME 4501-Lab 2- Spectrum Analysis System 3" from D2L.
6. Compare the natural frequency obtained from the theoretical, experimental and power spectrum for System 3 and comment on the possible reasons for the differences.

D. Finding the Damping Constant of Underdamped System

1. Download "Lab 2 Notes-Calculating the Damping Constant" document from D2L.
2. Watch "Lab 2 Calculating the Damping Constant" video form D2L.
3. Plot time vs acceleration for each system.
4. Calculate the damping constant of each system. Please show all your calculations below.

System 1:

System 2:

System 3:

E. Critical Thinking Questions

Please answer the following questions briefly.

1. In vibration analysis, can damping always be disregarded? Does damping have an effect on natural frequency?

2. How do you connect several springs to increase the equivalent stiffness? What is one example from industry or other real-life situations where this occurs?

3. What causes decay in the amplitudes of vibration?

4. What parameter(s) inversely effect the natural frequency?