

Name \_\_\_\_\_ Date \_\_\_\_\_

Partners \_\_\_\_\_

**Standing Waves in a Vibrating String: Lab #1**  
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**Objective:** to observe an interesting and beautiful phenomenon in order to learn some techniques to figure out its behavior mathematically.

**Equipment:** Function generator, mechanical vibrator, cable with banana to BNC connector, 2m string, 2m stick, pulley on a clamp, spacer pad to protect the table top, mass hanger, masses (20, 20, 50, 100, 100 grams)

**Sketch:**

**Note that there is a strong magnet in the base of the mechanical vibrator, so keep it away from computers and computer disks.**

**Background:** A string stretched horizontally between two supports illustrates simple harmonic motion if it is plucked or shaken. If the conditions are just right then standing waves can be set up in the string. These are often easily visible and very pretty.

We will investigate which physical variables influence the frequency of vibration of standing waves, and how that influence is expressed mathematically.

What are some of the variables which might affect the frequency of a standing wave?

**Definitions**, in words:

Frequency:

Wavelength:

Node:

Loop:

Monotonic:

**Experimental Procedure:**

**1. Set up the apparatus.** The variable frequency function generator and the string vibrator should be put near an electrical outlet. Connect the red and black “banana” leads to the vibrator in either order. The silver BNC connector at the other end of that cable goes to the (high impedance) terminal at the right end of the function generator. It installs with a push and a clockwise twist of the wrist.

DO NOT turn on the function generator yet. Select the “sine wave” button and the “10x multiplier” setting. This means that the machine will generate a frequency of “dial” times “multiplier”, for instance, 2 Hz \* 10 = 20 Hz. Note that “\*” means multiplication.

Use the spacer to protect the table top and clamp the pulley to the table edge farthest from the electrical outlet. Use the washer or a slipknot in one end of the string to hold the mass hanger. Thread the other end of the string through the little hole in the top of the vibrator. Run the string from the vibrator loosely over the pulley. Set the string length to 1.8 meters from the top of the vibrator to the top of the pulley by pulling the string through the top of the vibrator. Screw it down tightly.

Attach the mass hanger and another 50 grams, making 100 grams (0.1 kg) total.

**2. Data on number of loops**

Now plug the function generator into an electrical outlet. Turn on the function generator. Rotate the Amplitude knob clockwise to about half of its maximum.

Slowly turn the dial until you produce a standing wave in the string. Scan back and forth slowly between 5 and 20 on the frequency dial to find the maximum amplitude you can. Count the number of loops in the wave.

Number of loops \_\_\_\_\_ . Frequency \_\_\_\_\_ .

Turn the dial some more until a different standing wave is found.

Number of loops \_\_\_\_\_ Frequency \_\_\_\_\_

Now make a working hypothesis: More loops require \_\_\_\_\_ frequency.

Carefully scan the frequency dial and record the frequency for standing waves of 1 to 5 loops. (Note that the higher number of loops require a very gentle delicate touch.) Record your data in the data table on the last page.

**3. Data on tension mass**

Now let’s explore the effect of tension mass on the frequency of the standing waves. Set the apparatus for the proper frequency for  $L=1.8$  meters,  $T=.1$  kg and  $N=3$  loops. Now turn off the function generator and change the tension mass to 120 grams. (Remember that the mass hanger is already 50 grams.) Turn the generator on again and search for the proper frequency for three loops with this tension mass (120 grams).  $F =$  \_\_\_\_\_

Try it for a mass of 140 grams.  $F =$  \_\_\_\_\_

Now make a working hypothesis: Larger tension mass makes the frequency \_\_\_\_\_.

Let’s check this out in detail by taking more data for the same string length ( $L=1.8$  m) but for various tension masses and numbers of loops. Record your data in the data table.

#### 4. Data on length of string

Now let's investigate the effect of the length of the string on the frequency of the standing waves.

You can adjust the length of the string by loosening the tiny screw on the top of the vibrator, sliding the string through it, and re-tightening the screw. Take data for lengths of 1.30 m and .90 m. Record your data in the data table.

#### 5. Spreadsheet

In order to make a mathematical model of these data we want to manipulate them in many ways. The easiest way to do this is to type the data into a spreadsheet first.

Please use the Excel "vibrating string template" already on the computer. After typing the first entry save the spreadsheet with a different name, such as "stringChris" or some such. Data entries should be numeric only (no units).

#### 6. Qualitative Conclusions

As  $N$ , the number of loops, increases, then  $F$ , the frequency \_\_\_\_\_.

F  
|  
|\_\_\_\_N

As  $T$ , the tension mass, increases, then  $F$ , the frequency \_\_\_\_\_.

|  
|\_\_\_\_T

As  $L$ , the length of string, increases, then  $F$ , the frequency \_\_\_\_\_.

|  
|\_\_\_\_L

#### 7. Quantitative Conclusions (Graphs and equations)

If a graph is not linear, then try fitting a power law to it.

For length = 1.8 m,  $T = .1$  kg make a graph of frequency  $F$  vs. number of loops  $N$ .  
Is it monotonic? \_\_\_\_\_ Is it linear? \_\_\_\_\_ Equation  $F \sim N$

For length = 1.8 m,  $N = 2$  make a graph of frequency  $F$  vs. tension mass  $T$ .  
Is it monotonic? \_\_\_\_\_ Is it linear? \_\_\_\_\_ Equation  $F \sim T$

For  $T = .1$  kg,  $N = 3$  make a graph of frequency  $F$  vs. string length  $L$ .  
Is it monotonic? \_\_\_\_\_ Is it linear? \_\_\_\_\_ Equation  $F \sim L$

Putting these all together  $F \sim N^T L$

For each member of the lab team print out a copy of the spreadsheet with small embedded graphs.

#### 8. Applications to everyday life:

Data Table

L, Length of string (meters)	T, Tension mass (kilograms)	N, Number of loops	F, Frequency (Hertz)
1.8	.100	1	
1.8	.100	2	
1.8	.100	3	
1.8	.100	4	
1.8	.100	5	
1.8	.050	1	
1.8	.050	2	
1.8	.050	3	
1.8	.050	4	
1.8	.050	5	
1.8	.140	1	
1.8	.140	2	
1.8	.140	3	
1.8	.140	4	
1.8	.140	5	
1.8	.300	1	
1.8	.300	2	
1.8	.300	3	
1.8	.300	4	
1.8	.300	5	
1.3	.100	1	
1.3	.100	2	
1.3	.100	3	
1.3	.100	4	
1.3	.100	5	
.9	.100	1	
.9	.100	2	
.9	.100	3	
.9	.100	4	
.9	.100	5	