Standing Waves Activity

Purpose

Students will Set-up the resonant modes of a stretched steel wire. The students will use an electromagnetic driver connected to a function generator to establish the first four harmonics of a stretched wire. After the students become comfortable with the equipment and the physics principles, the students will be required to achieve resonance of a stretched wire under specific conditions.

Part I: Set-up the stretched wire and function generator.

SAFETY NOTICE: Be aware the 1 Kg mass is essentially being suspended by the wire of the sonometer. If the wire should break, the 1 Kg mass will fall to the floor. Do not allow any body parts to be located near the potential impact point of the 1 Kg mass.

Place the wire on the Pasco Sonometer and place the bridges (L shaped brackets) on the sonometer such that they are 60cm apart. Place the driver in between the bridges such that is approximately 5cm from one of the bridges. Hang the 1.0 Kg mass from the second notch on the lever that is closest to the wire. Use the knob to adjust the lever such that it is horizontal. The tension of the wire is determined by multiplying the amount of downward force acting on the lever by two (the force is multiplied by two because the downward force is being applied to the second notch.

$$T = 2F$$

The wires for the sonometer are color coded. The end of the wire with the ring should match a color below.

Linear Densities of Sonometer Wires by Color				
Silver -- 0.39 g/m	White -- 0.78 g/m	Orange -- 1.12 g/m	Yellow -- 1.5 g/m	Blue -- 1.84 g/m

The provided multimeter will be used as an AC voltmeter to monitor the amplitude of the sinusoidal output of the function generator. The red port of the multimeter (VΩ) should be connected to the red output of the function generator. The black port of the multimeter (COM) should be connected to the black output of the function generator.

The electromagnetic driver should also be connected to the red and black outputs of the function generator. The wires used for the multimeter should be stackable, and the red wire and black wire of the electromagnetic driver should be plugged into the outputs of the function generator simultaneously with the multimeter.

Part II: Theoretically Determine the Fundamental and the Next Two Harmonics for your Wire.

Knowing the tension, linear density, and length of the wire is required to predict the fundamental frequency and higher harmonics. Specifically, these oscillation frequencies of the wire are related to the velocity of the wave along the wire as well as the frequency of the wave. Calculate the frequency and wavelength for the Fundamental mode of the wire, 2nd Harmonic, and 3rd Harmonic. Also sketch the Resonant Modes of your wire and label the location of all nodes if you define the location of one of your bridges to be located at 0cm and the other bridge to be located at 60cm. (Hint: Nodes will be located at the bridges for all of the resonant modes.)

Part III: Find the Lowest Three Resonant Modes for your Stretched Wire.

Use the function generator and electromagnetic driver to establish the first three resonant modes for your wire. The frequencies that you calculated in Part II may be used as a starting point. However, when setting the function generator frequencies, your calculated frequencies found in Part II will have to be divided by two for each of the corresponding resonant modes**.

(Frequency of Wire) = 2 x (Function Generator Frequency)

1. Set your Multimeter dial to the 200VAC setting (200 V~).
2. Turn on your function Generator (make sure it is plugged in).
3. Adjust the amplitude knob of the function generator such that the voltage is between 2.0 and 4.0 Volts.
    a. You should start with the lowest voltage possible for each resonance mode. You will probably need to increase the voltage as you proceed to higher resonance modes. However using too high of a voltage, will cause your steel wire to contact the electromagnetic driver. In this case, it will be more difficult to achieve resonance.
4. Use the push buttons on the Function Generator to select the Sinusoidal Waveform.
5. The frequency is adjusted by turning the "Adjust" knob of the Function Generator.
6. The "Range" buttons on the Function Generator can be used to alter the significant digits of the frequency display.
7. A small piece of wire (such as a piece of a paperclip) can be looped on to your stretched steel wire to help facilitate finding the resonant frequencies. If the small loop of wire is located near an anti-node, the small loop of wire will vibrate more vigorously as a resonant frequency is approached. When the frequency of the wire is very near a resonant frequency, the small loop may need to be moved to a node to allow the wire to achieve the maximum amplitude which indicates the resonant frequency has been achieved. After the resonant mode is achieved, the small loop of wire can also be slid along the stretched wire using the tip of a pen or pencil to help locate the nodes of the stretched wire.

** Why do the frequencies need to be divided by two? The electromagnetic driver uses an electromagnet to pull the steel wire. As electric current flows through a wire that is wound around a steel core, a magnetic field is created just like an ordinary bar magnet. But in this case, the current is not constant. The current is delivered by the function generator in the form of a sine wave. Over a complete period, a sinusoidal waveform begins at zero, ramps up to a positive peak, ramps back down to zero, approaches a negative peak, and then returns to zero. Each time the waveform pass through zero, the electromagnet is turned off, and the wire is released. So if the function generator is set to 100Hz, the wire is pulled 200 times per second by the electromagnet. Therefore a pulse is being sent down the wire at a frequency of 200Hz.

Part IV: Placing you Wire in a Resonate mode as specified by your TA

Your TA will visit your station and provide conditions for you to establish resonance on your wire. At this time, your TA will remove your bridges from your station, and you will be required to calculate the Function Generator frequency that will be required to establish resonance for the conditions provided by your TA. After you have calculated the frequency necessary to place your wire in resonance for your given conditions, and recorded it on your data sheet using a pen, your TA will return to your station to test your prediction.

Part IV. Clean-up

To avoid a grade deduction, make sure you do the following.

Organize your station. Turn-off the multimeter. Turn-off and unplug the Function Generator. Remove the mass from the lever.

Name: _____ **Name: _____**

Name: _____ **Name: _____**

Data Sheet
Standing Waves Activity

Hints:

1. Change the frequency of the Function Generator slowly. You must allow the steel wire to 'settle'. If you change the frequency too fast, the wire will not have an opportunity to achieve resonance, or you may skip over the resonance frequency. Patience is critical.
2. Depending on your conditions, one or two of the harmonics may be difficult to acquire. Again, patience and an understanding of the underlying physical principals are critical to your success.
3. You may find that it is easier to approach the resonant frequency for each harmonic from a particular direction. For some individuals it may seem easier to achieve resonance while raising the frequency towards the resonant frequency. For others, it may seem easier to achieve resonance by approaching the resonant frequency from a higher frequency and slowly lowering the frequency.
4. Adjust your predicted Function Generator Frequency based on data collected in Part III.

Part II (30 points total)

Fundamental Harmonic

Calculated Wire Frequency: _____ Wavelength: _____

Sketch:

Part II (Continued)

Second Harmonic

Calculated Wire Frequency: _____ Wavelength: _____

Sketch:

Third Harmonic

Calculated Wire Frequency: _____ Wavelength: _____

Sketch:

Part III (30 points total)

Resonance Mode	[A] Calculated Function Generator Frequency (Hz)	[B] Actual Function Generator Frequency (Hz)	Error $\frac{\lvert A-B \rvert}{B} x100\%$
Fundamental			
2nd Harmonic			
3rd Harmonic			

You may use the above information to adjust your ***prediction*** for part IV. For instance, make an appropriate adjustment if your calculated Function Generator Frequency is always a little lower than the actual Function Generator Frequency.

If your error is greater than 10%, check your calculations carefully. Also make sure the lever arm is horizontal. (i.e. When the mass is hanging on the lever arm, the angle between the lever arm and the long arm of the hanging mass should be 90^0.) The lever arm can be adjusted by turning the knob.

Provide a sample calculation for at least one of the resonance modes below.

Part IV (40 points total)

Bridge Separation 55cm 50cm 45cm 40 cm (Circle one)

Harmonic 2^{nd} 3^{rd} (Circle one)

Use a pen to record the ***predicted*** Function Generator frequency below, and your TA will circle and initial your prediction and return your bridges. With your bridges separated by the appropriate distance, fine tune the Function Generator frequency to establish the resonance mode that corresponds to the Harmonic you have been given. After you have established the appropriate resonance mode, your TA will return to your station and record the Function Generator Frequency. Your grade for this section will be based on the table below.

Calculated Function Generator Frequency _____ (Hz)

A. ***Predicted*** Function Generator Frequency _____ (Hz)

B. Actual Function Generator Frequency as witnessed by the TA _____ (Hz)

Percent Error $= \frac{|A-B|}{B} x100\% =$ _____

Circle the groups score

Percent Difference	<= 1.0%	<= 1.5%	<= 2.0%	<= 2.5%	<=3.0 %	> 4.0%
Points	40	38	34	31	21	11

Five points will be deducted for each task that is not performed before you leave your station.

Turn-off Multimeter _____ Turn-off Function Generator _____

Remove Mass from Lever _____