Online Lab: Vibrating Strings

Name: ______ Date: ______

Instructor: ______ Section: ______

Objective:

The purpose of this experiment is to observe the relationships between frequency, wavelength, speed of the wave and look at how they change with varying Tension.

General Theory:

Standing waves (stationary waves) are produced by the addition of two traveling waves, both of which have the same wavelength and speed, but travel in opposite directions through the same medium. Figure 1 shows a wave on a string which moves to the right and reflection from a fixed end produces a left moving wave. Where the two waves are always 180° out of phase, very little motion occurs (none if the amplitudes are the same). Such places are called nodes (see Figure 1). Where the two waves are in phase, the motion is maximum. These positions are call anti-nodes.

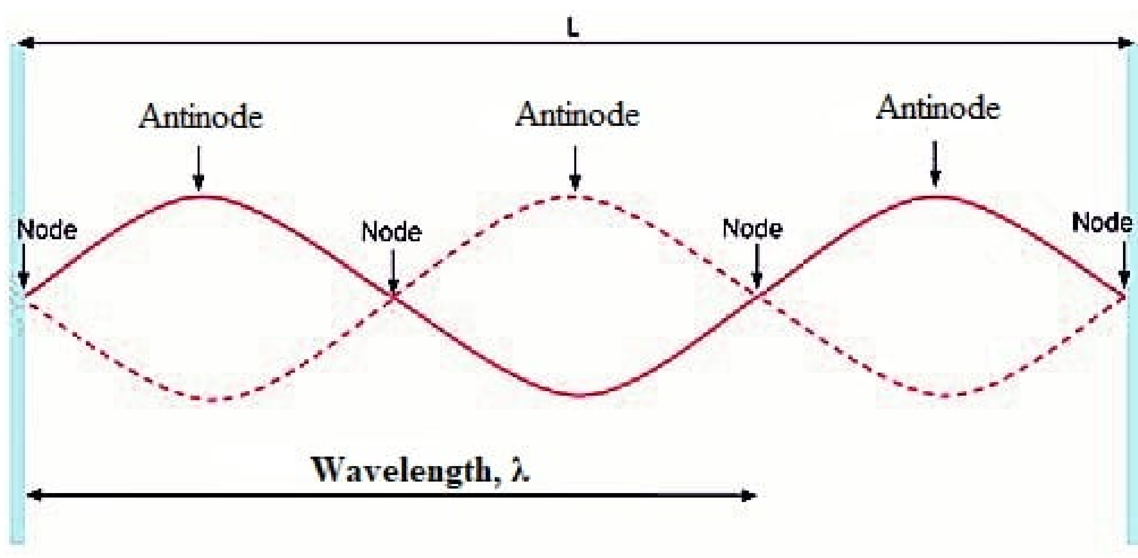


Figure 1: Stationary Wave on a String

Theory: Standing Waves in Strings

A stretched string has many natural modes of vibration (three examples are shown in Figure 2). If the string is fixed at both ends then there must be a node at each end. It may vibrate as a single segment, in which case the length (L) of the string is equal to 1/2 the wavelength (λ) of the wave (See Figure 1). It may also vibrate in two segments with a node at each end and one node in the middle; then the wavelength is equal to the length of the string. It may also vibrate with a larger integer number of segments. In every case, the length of the string equals some integer number of half wavelengths. If you drive a stretched string at an arbitrary frequency, you will probably not see any particular mode; many modes will be mixed together. But, if the tension and the string's length are correctly adjusted to the frequency of the driving vibrator, one vibrational mode will occur at a much greater amplitude than the other modes.

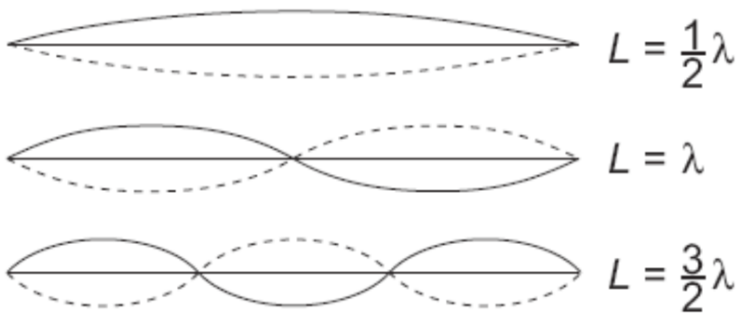


Figure 2: Modes of Vibration

For any wave with wavelength λ and frequency f, the speed, v, is

$$v = \lambda f \tag{1}$$

For a string of Length L, and both ends are fixed

$$\lambda_n = \frac{2L}{n}, \tag{2}$$

where n = 1,2,3, ...

Then with equations (1) and (2) we find that the number of allowed frequencies are:

$$f_n \ = \ \frac{v}{\lambda_n} \ = \ \frac{nv}{2L} \tag{3}$$

for n = 1,2,3, ...

Online Vibrating Strings Experiment Instructions.

1. Go to the following website:
   https://phet.colorado.edu/en/simulation/wave-on-a-string

2. Press the Play Button on the "Wave on a String" simulation to open the simulator.

3. Figure 3 shows an example of what you should see on your screen.

4. Play with the simulator for a few minutes to get comfortable with it.

5. **Fill in the Blank**. Choose from the given words below the correct word that matches the definition for each of the Standing Wave property below.

   Each word is only used ONCE.

Wave Frequency	Wave Speed	Amplitude	Wavelength

   (a) The ______ is the maximum distance of the object from its equilibrium position.

   (b) The ______ is the number of complete cycles or vibrating per unit of time.

   (c) The ______ is the speed at which a particular part of the wave moves through the medium.

   (d) The ______ is the distance between two successive points that behave identically.

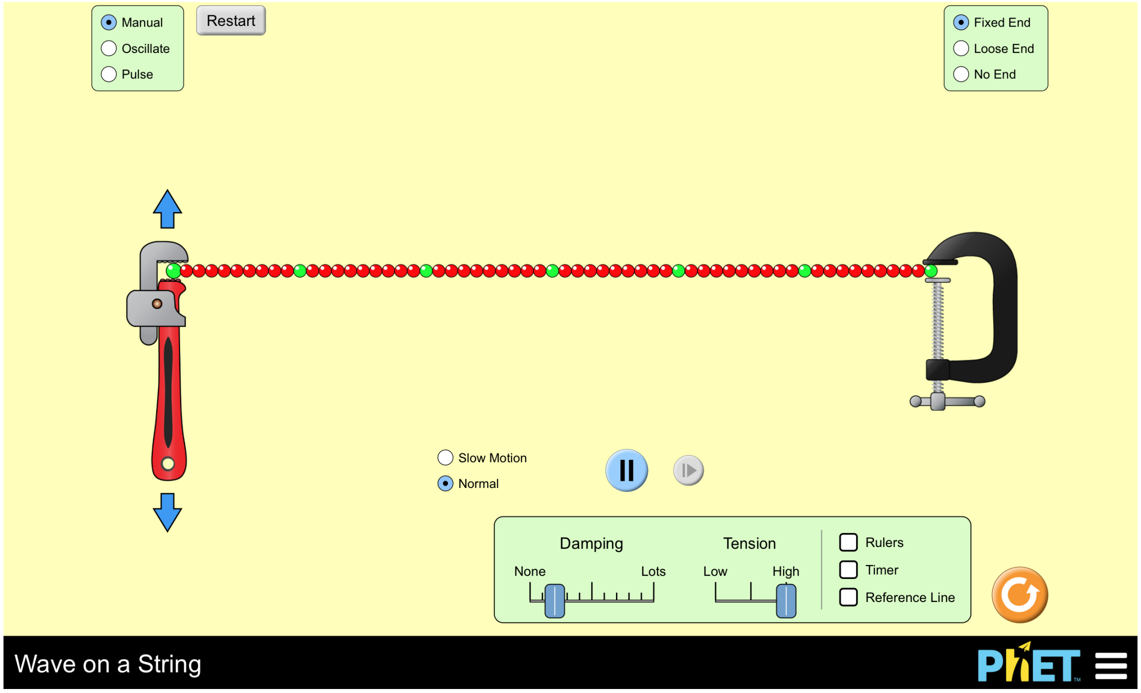


Figure 3: Initial Configuration after opening the Wave on a String Simulator

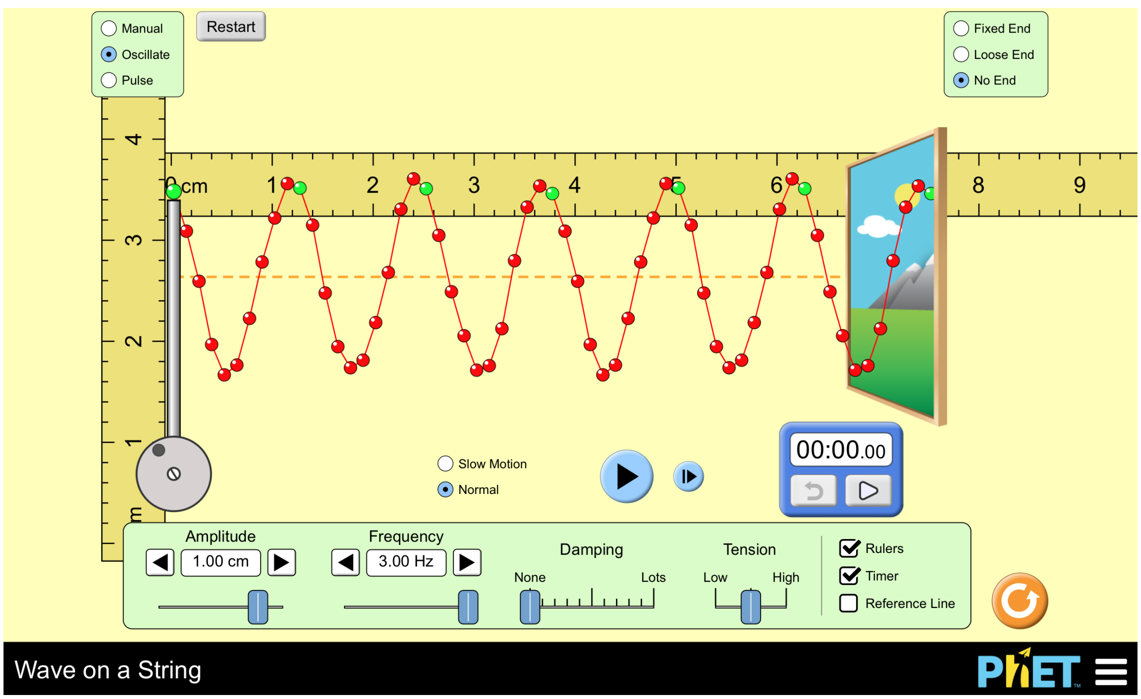
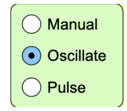


Figure 4: Example: After setting up and running the Wave on a String Simulator

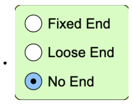
Relationship between Frequency and Wavelength.

1. Setup the Simulator with the following settings. (see Figure 4)

   (a) Set the **Wave** to Oscillate (green box in upper-left corner).

   (b) Set the **String** to No End (green box in upper-right corner).

   (c) Set the **Amplitude** to 1.0 cm (bottom Control Panel, See Figure 5).

   (d) Set the **Damping** to None (bottom Control Panel, See Figure 5).

   (e) Set the **Tension** to Medium and Set the **Motion** to Slow Motion.

   (f) **TURN ON** the Rulers and the Timer (bottom Control Panel, See Figure 5).

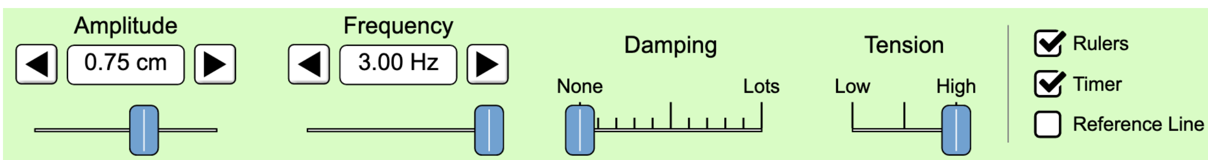


Figure 5: Wave on a String Simulator Control Panel

2. **Using the setting above, determine the relationship between Frequency and Wavelength**. Record your measurement of Wavelength in Table 1 below to the nearest tenth of a centimeter. For a very long wavelength, measure half a wave and multiply by two.

Table 1: Frequency vs Wavelength

Frequency (Hz)	**Wavelength (cm)**
3.0 Hz	
2.0 Hz	
1.5 Hz	
1.0 Hz	
0.5 Hz	

Tension and Wave speed.

1. Setup the Simulator with the following settings.
    (a) Set the **Wave** to Pulse (green box in upper-left corner).
    (b) Set the **String** to Fixed End (green box in upper-right corner).
    (c) Set the **Amplitude** to 1.0 cm (bottom Control Panel, See Figure 5).
    (d) Set the **Damping** to None (bottom Control Panel, See Figure 5).
    (e) Set the **Tension** to Low (bottom Control Panel, See Figure 5).
    (f) Set the **Motion** to Slow Motion (above the Control Panel).
    (g) **TURN ON** the Rulers and the Timer (bottom Control Panel, See Figure 5).
2. **Measure** and **Record length of string here.** $L =$
3. The length of one round trip is 2 × L. Record this value in the (L_1) column of Table 2.
4. Click the Pulse Generator Button to send a pulse through the string. 
5. **Measure** the time it takes for the pulse to travel one round trip. Record this value in the (t_1) column of Table 2.
6. **Measure** the time it takes for the pulse to travel three round trips. Record this value in the (t_3) column of Table 2.
7. **Calculate** $v_{wave} = L_1 \ / \ t_1$. Record this value in Table 2.
8. Repeat Steps 5-7 for Medium and High Tension.

Table 2: Tension and Wave speed

Tension	L_1 (cm)	t_1 (s)	t_3 (s)	v_{wave} (cm/s)
Low				
Medium				
High				

9. **How does the Tension affect the speed of a wave?**

Standing Wave: Modes of Vibration.

1. Setup the Simulator with the following settings.
   (a) Set the **Wave** to Oscillate and Set the **String** to Fixed End.
   (b) Set the **Damping** to None and Set the **Motion** to Slow Motion.
   (c) Set the **Amplitude** to 0.2 cm (bottom Control Panel, See Figure 5).
   (d) Set the **Tension** to Medium (bottom Control Panel, See Figure 5).
   (e) **TURN ON** the Rulers and the Timer (bottom Control Panel, See Figure 5).
2. **Measure** and **Record length of string here.** $L =$
3. Use your results from Table 2 for v_{wave} for Medium Tension for this Analysis.

Analysis: Second Harmonic Standing Wave

1. Determine the wavelength, λ.

2. Calculate the Frequency, f. Use $v_{wave} = \lambda * f$.
3. Input this frequency into the Simulator. Press **RESTART** and Verify your result.

Analysis: Third Harmonic Standing Wave

1. Determine the wavelength, λ.

2. Calculate the Frequency, f. Use $v_{wave} = \lambda * f$.
3. Input this frequency into the Simulator. Press **RESTART** and Verify your result.

Relationship between Frequency & Wavelength at Varying Tension.

1. Setup the Simulator with the following settings.
   (a) Set the **Wave** to Oscillate and Set the **String** to No End.
   (b) Set the **Damping** to None and Set the **Motion** to Slow Motion.
   (c) Set the **Tension** to Low.
   (d) Set the **Amplitude** to 0.75 cm.
   (e) **TURN ON** the Rulers and the Timer.
2. **Measure** and **Record length of string here.** $L =$
3. Set the **Frequency** to 1 Hz.
4. **Measure** the time it takes for a wave to travel the length of the string t_1. Record your result in Table 3 below.
5. **Measure** the length of a single wave length, λ. Record your result in Table 3 below.
6. **Repeat Steps 3-5** for Frequency 2 Hz and 3 Hz.
7. **Repeat Steps 3-6** for Medium and High Tension.
8. Calculate v_{wave} column using v_{wave} = L / t_1.
9. Calculate each row in the $f \times \lambda$ column.

Table 3: Frequency and Wavelength with Varying Tension

Tension	f (Hz)	t_1 (s)	λ (cm)	v_{wave} (cm/s)	$f \times \lambda$
Low	1				
Low	2				
Low	3				
Medium	1				
Medium	2				
Medium	3				
High	1				
High	2				
High	3				

Conclusions:

1. If the tension remains constant and the frequency increases, what happens to the wavelength?

2. Is there any pattern in the last two columns of the table (v_{wave} and $f \times \lambda$)?

3. What is the relationship between frequency f, wavelength λ and speed of a wave v_{wave}?