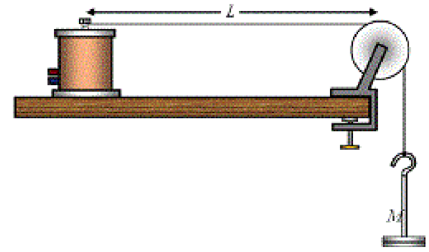
Group Members: Tanisi Tripathi, Gigi Gong, Maddy Xiong, Pooja Birla, Junyu Xu

LAB. SPEED OF A STANDING WAVE

AP PHYSICS I

Driving Question | Objective

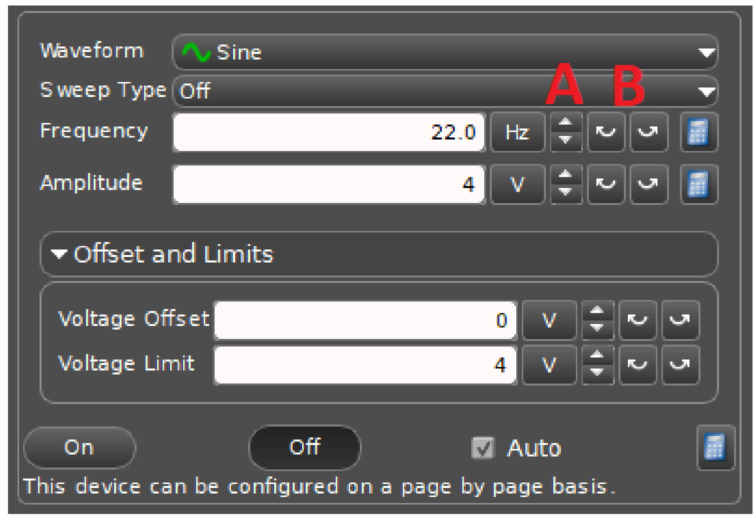
How can we determine the speed of a wave if it appears to be standing? What kind of harmonic frequencies create standing waves? In this lab, we will be measuring wavelengths and frequencies to determine the wave speed using the wave speed equation.



Materials and Equipment

- Mechanical Oscillator
- String
- Pulley
- Hanging masses
- Meter Stick

Part 1 Procedure – Wavelength vs. Period



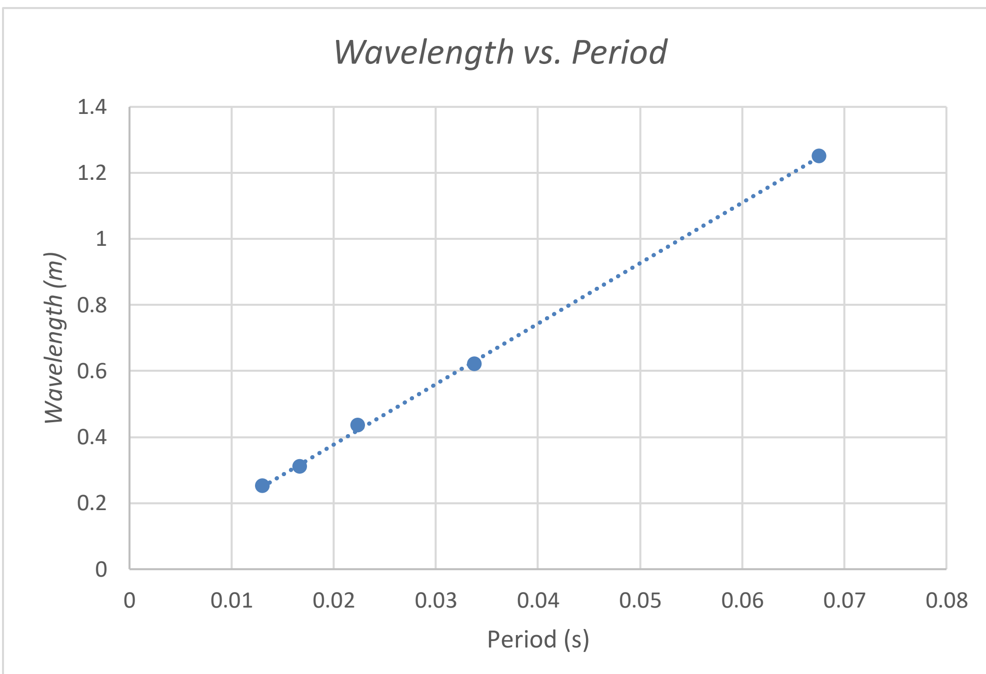
1. Begin by attaching a string to your mechanical wave generator and hanging mass with string and placing the mass over the pulley, as seen in the image on the top right of this page.
2. Place a 50g mass on your mass hanger, but please note the mass hanger also has its own mass of 5g. This will place a total hanging mass of 55g. Calculate and record the tension in the string.
3. Open the Capstone file for this lab. This file will be used to control the frequency of the up and down motion of your mechanical wave generator and will create transverse waves within the string.
4. In the file, set the Voltage Limit and Amplitude to 4V and set your Waveform to “Sine”. Then press “On”.
5. Begin scanning different frequencies by either manually typing in a frequency value or adjusting the values up or down with the up/down arrows labeled “A” in the diagram to the right. To switch which units you will adjust (tens, ones, decimal), press the left or right arrows labeled “B” in the diagram to the right.
6. Adjust the frequency until you produce the fundamental harmonic (1^{st} harmonic), which should have one antinode in the center of the string. Record the frequency that was used the create this standing wave and then convert it to period. Then, measure the wavelength of the wave using your meterstick. Please be mindful on measuring the wavelength *correctly*.
7. After you have recorded the Wavelength and Period for the 1^{st} harmonic, begin rescanning a different frequency to find the 2^{nd} -5^{th} harmonics. Record their wavelengths, frequencies, and periods accordingly.

Part 1 Data – Wavelength vs. Period

1. Record the tension in your string here:
   a. Tension = 0.539 N f
2. In the table below, record your Frequency, Period, and Wavelength of each standing wave you created.

Harmonic #	*f*, Frequency (Hz)	x-variable *T*, Period (s)	y-variable λ, Wavelength (*m*)
1st	14.8	1/14.8	1.25m
2nd	29.7	1/29.6	0.62m
3rd	44.7	1/44.7	0.435m
4th	59.9	1/59.9	0.31m
5th	76.8	1/76.8	0.25m

3. In the graph below, import your data to create a Wavelength vs. Period graph.



4. Place a linear fit to your data. What is the value of slope for your graph? What aspect of the wave does this slope represent?

The value of the slope of the graph is 18.311. The aspect of the wave that the slope represents the wavelength over the period which is the ___________.

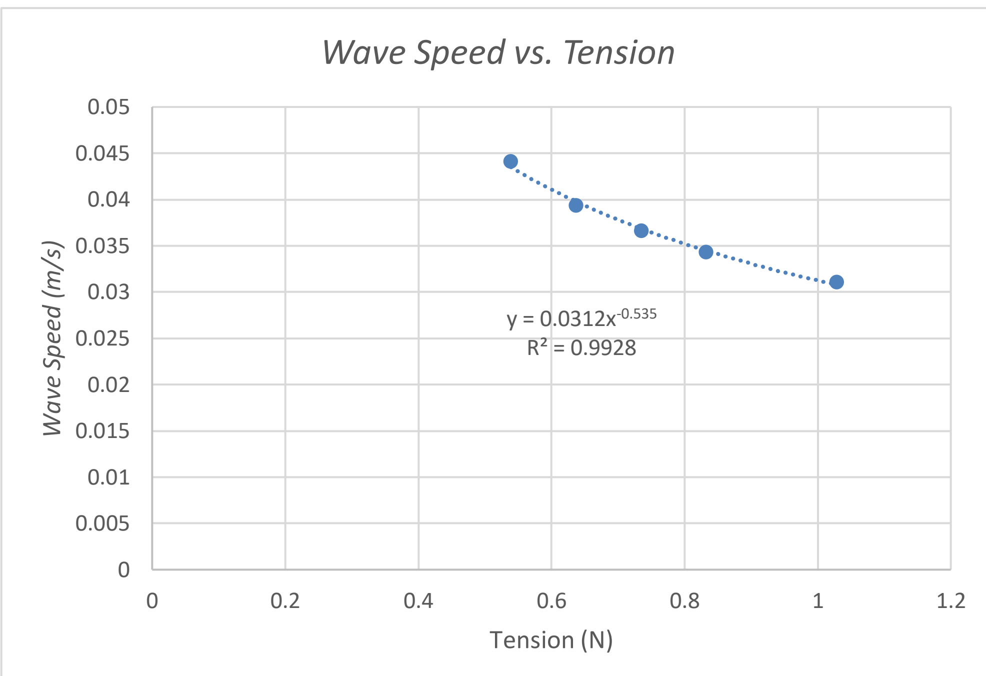
5. Based on your data, how would you establish the equation for wave speed, using only the terms λ and *T*.
   a. $\upsilon =$

Part 2 Procedure and Data – Wave Speed vs. Tension

1. In this section you will determine how the tension in the string affect the speed of the wave. Begin by placing 50g of mass on your mass hanger, but please note that the mass hanger also has its own mass of 5g. This will place a total hanging mass of 55g. Calculate and record the tension in the string.
2. Scan the frequencies to find **any** of the harmonics. It does not have to be the 1st harmonic.
3. Record the Frequency, Period, and wavelength of your standing wave.
4. Follow the above 3 procedures again with a new hanging mass, value. However, do not go below a hanging mass of 50g, as the mass of the string itself will begin to skew your data. Also, do not go above a hanging mass of 250g, as going beyond this can place too much force on the mechanical oscillator. Do this for a minimum of 5 different hanging masses.

	***x*-variable**				***y*-variable**
***m*, Hanging Mass (*kg*)**	**F_T, Tension (*N*)**	***f*, Frequency (Hz)**	***T*, Period (s)**	**λ, Wavelength (*m*)**	***v*, Wave Speed (*m/s*)**
0.055	0.539	28.8	1/28.8	1.27	1.27/1/28.80.
0.065	0.637	32.3	1/32.3	**1.27**	1.27/1/32.3
0.075	0.735	34.7	1/34.7	1.27	1.27/1/34.7
0.085	0.833	37.0	1/37	1.27	1.27/1/37
0.105	1.029	40.9	1/40.9	1.27	1.27/1/40.9

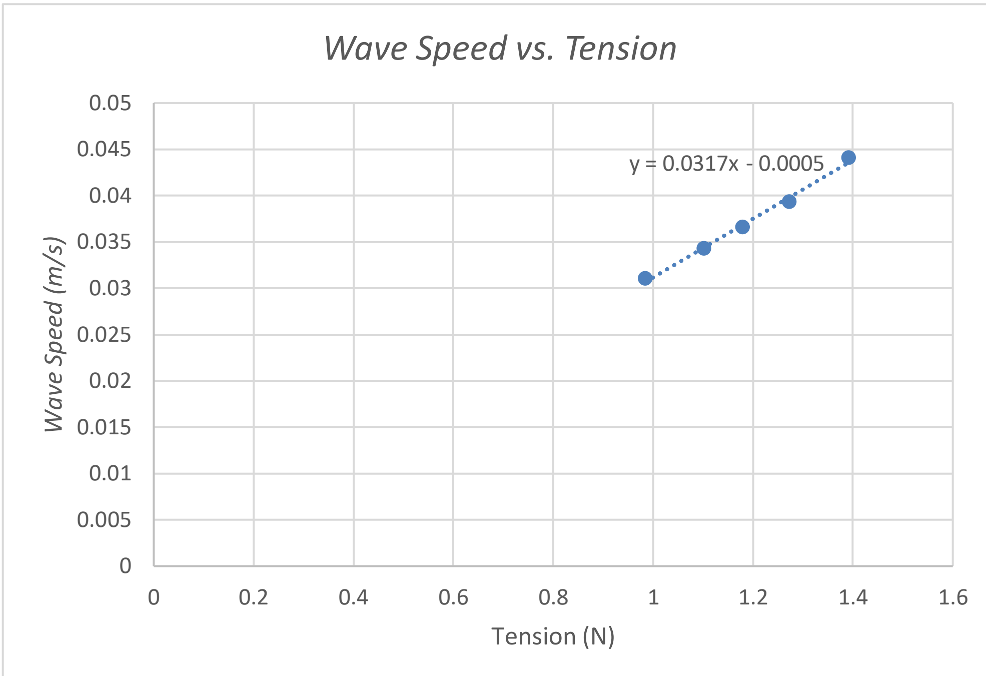
5. Import your data to the chart below and display a power regression.



1. What kind of relationship exists between wave speed and tension?

There is a inverse relationship between the wave speed and the tension. As the tension increases the wave speed decreases

2. Linearize your data in the graph below. Then, rename the axes appropriately and display a linear regression.



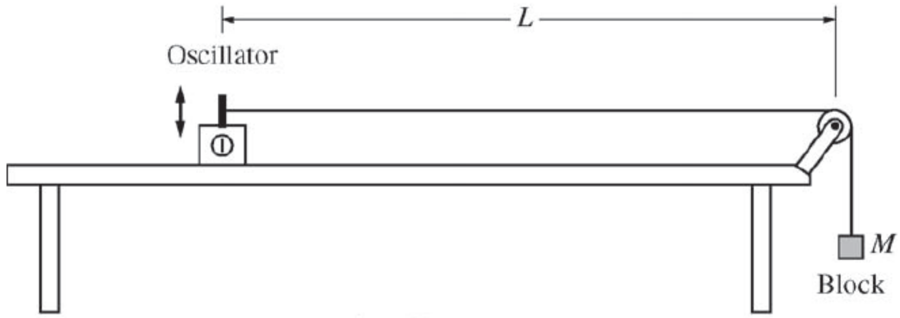
3. Based on the accepted equation, $v_{string\ wave} = \sqrt{\frac{F_T}{\mu}}$, where μ represents the linear mass density of your string, what would the slope of your graph above represent?

The slope of the graph above, 0.0317, represents the velocity of the string wave.

4. Using your graph above, what would you say the value of your string's linear mass density is, expressed in kg/m?

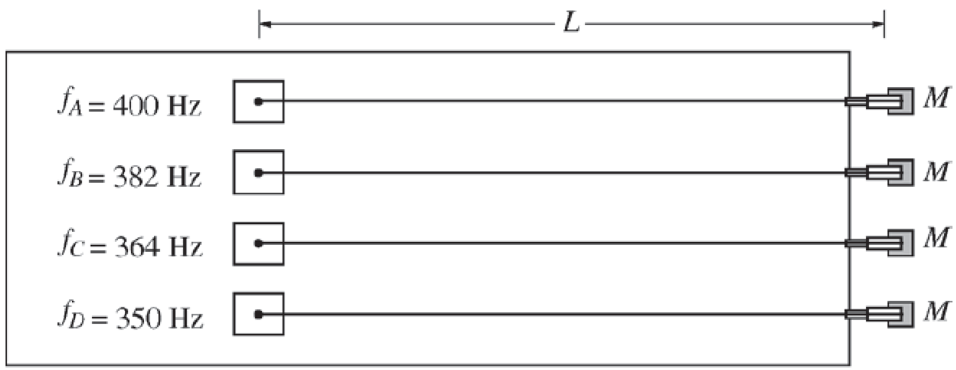
The linear mass density of this graph represented by the u in the graph. In the case of this string the linear mass density would be 0.0004 kg/m

AP Exam Question Free Response – Standing Waves Q5 (2015)



Side View

The figure above shows a string with one end attached to an oscillator and the other end attached to a block. The string passes over a massless pulley that turns with negligible friction. Four such strings, A, B, C, and D, are set up side by side, as shown in the diagram below. Each oscillator is adjusted to vibrate the string at its fundamental frequency f. The distance between each oscillator and pulley L is the same, and the mass M of each block is the same. However, the fundamental frequency of each string is different.



Top View

The equation for the velocity v of a wave on a string is $v = \sqrt{\frac{F_T}{m/L}}$, where F_T is the tension of the string and m/L is the mass per unit length (linear mass density) of the string.

a) What is different about the four strings shown above that would result in their having different fundamental frequencies? Explain how you arrived at your answer.

Since the strings all have the same length and the wavelength depends on the length, all four waves will have the same wavelengths. Since all the wavelengths are the same different frequencies will correspond to different parts of the string

b) A student graphs frequency as a function of the inverse of the linear mass density. Will the graph be linear? Explain how you arrived at your answer.

The graph would not be linear because It is not proportional to the frequency?