

Standing Waves lab (VIRTUAL) Name: _____

Theory: If you create standing waves on a string with fixed ends at a fixed tension, you can get different numbers of antinodes by changing the vibrating frequency. If a frequency f produces the fundamental mode, then the harmonic series $2f$, $3f$, $4f$, etc., produce standing waves with two, three, and four antinodes, respectively. On a guitar string, a player creating an appropriate node can produce those harmonic frequencies.

All of that assumes that the string and its tension stay consistent. We can also produce different standing waves by taking a given string and frequency and changing the tension.

A string has a property called *mass density* (labeled by the Greek letter μ), which is its own mass divided by its length. In SI units, μ is written in the units kg/m. If we use the symbol F_T for the tension on a string (in Newtons), the wave speed is given by the equation

$$v = \sqrt{\frac{F_T}{\mu}}$$

In this lab, the tension is provided by a hanging mass. The tension that a hanging mass produces in a string is equal to mg , where g is the acceleration due to gravity (9.8 m/s^2). What this equation will let us do is *predict* what hanging mass produces different standing waves.

This lab will walk you through a set of these predictions.

Question 1: Take the wave speed equation above and solve it for F_T . (that is, get the tension force by itself on one side.)

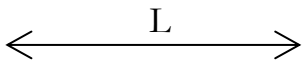
Question 2: Practice this: if the tension force is 2.50 N, calculate the mass in kg needed to produce that tension.

VIDEO: You can visit our video walkthrough of the lab:

<https://www.youtube.com/watch?v=CE3q0IKfuMc>

Question 3: Look at the pictures in the first few seconds of the video. What is the mass of the string being used?

The lab uses a frequency of 35 Hz and a length of string between the machine and the pulley of 1 m. Complete the table below to get the wavelength and wave speed for the five cases explored in the video. You shouldn't need data from the video to do this part.

# of antinodes	Draw a small picture 	Distance between consecutive antinodes (m)	λ (m)	Wave speed (m/s)	Wave speed ² (m ² /s ²)
6					
5					
4					
3					
2					

Question 4: What is the mass density of a string one meter long that has the mass our string does in the video?

Question 5: Look at the two-antinode case. Using your answer to Q1, steps in Q2 and answer to Q4, predict what mass is hanging off the string in that case.

If that is your final guess, you will be off by nearly a factor of two. Let's figure out why.

Question 6: Get this by looking around the trials on the video. Other than the number of antinodes on the standing wave, what is the biggest difference in the setup between the first and last cases in the video?

We need to find μ appropriately by using the whole length of string. The standing wave part is a meter long, but it turns out you get much better results if you get mass density by dividing the string's mass by the **entire** length. Use the additional information below to complete the table:

# of antinodes	Length hanging past the pulley (m)	Actual mass density (kg/m)	Wave speed ² (m ² /s ²)	Predicted tension F_T (N)	Mass needed (kg)
6	0.31				
5	0.31				
4	0.33				
3	0.50				
2	0.98				

You should see that the mass density can be very different in this string depending on the mass used. We have less "elastic" string that wouldn't stretch as much, but it doesn't look as good in the demo.

Wrapup: Question 7: What are the main sources of measurement uncertainty in this experiment?

Question 8: The actual total hanging masses used in the video were 55, 80, 114, 205, and 335 g respectively. How well did your predictions agree? Are they all too high or low? This is a clue whether the errors are **random** or **systematic**.