Course and Section_______ Names ___________________________

Date___________ _________________________________

STANDING WAVE EXPERIMENT

Introduction

A standing wave is a combination of two propagating waves traveling in opposite directions with the same amplitude and wavelength. When a string is clamped at both ends and is driven sinusoidally, standing waves can be generated. In this experiment, you will study which values of masses and frequencies are necessary to generate standing waves.

Equipment

Oscillator, signal generator, aluminum track, C-clamp, green plastic cup, sand, masses, mass hanger, clump pulley, two banana cables, plastic cup for sand, meter stick, digital scale.

Theory

The possible wavelengths of a standing wave are

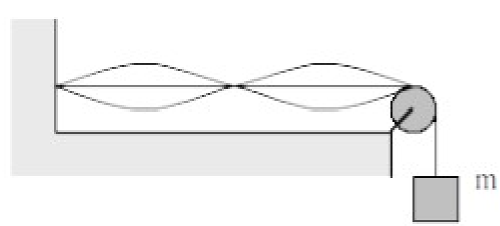
$$\lambda = \frac{2L}{n} \quad n = 1, 2, 3 \ldots \qquad (1)$$

where L is the distance between the two ends and n is the number of loops.
Using $v = \lambda f$ and $v = \sqrt{T/\mu}$ where: v is the velocity of the wave, T is the tension in the string and μ the mass per unit length, it follows

$$\lambda = \frac{1}{f}\sqrt{\frac{T}{\mu}} \qquad (2)$$

In this experiment a mechanical oscillator, powered by a sinusoidal signal generator, is used to generate standing waves of different wavelengths.

The tension is determined by the weight of a mass hanging by a pulley from one end of the string. The standing wave in the figure to the right shows two loops and three nodes (the points of destructive interference).



Combining equation (1) and (2) it follows

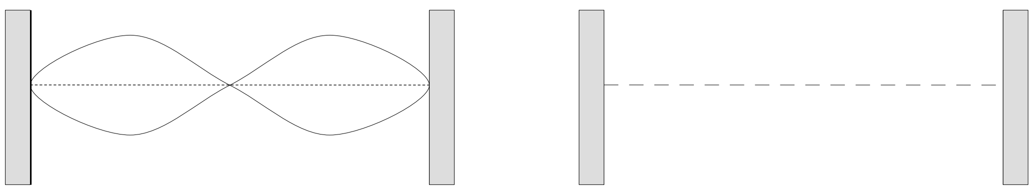
$$f = \frac{n}{2L}\sqrt{\frac{mg}{\mu}} \qquad (3)$$

Preliminary Questions

1. If a standing wave with 5 loops is created on a string of length 2.0 m, what is the wavelength of the standing wave?

2. Suppose you have established a standing wave on your string. If you pull down on the string to increase the tension *F* until another standing wave is created, will the wavelength of the new standing wave be greater or less than the first?

3. The following figure shows a standing wave on a string; if the tension is quadrupled, draw the new standing wave (constant frequency).



4. Refer to question 2. What if the tension is tripled, will you get a standing wave?3 Explain.

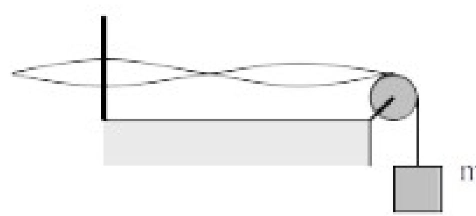
Procedure

5. Write below the mass per unit length of your string, ask your instructor or the TA.

μ = __________ (g/m)

In the following PART 1 and PART 2 your goal is to create standing waves of different wavelengths.

Note: you must consider only standing waves for which there is a node at the oscillator as shown in the figure at the bottom of the first page. In other words DO NOT consider the case where the amplitude is max at the oscillator as shown in the figure to the right. If you observe one of these standing waves, change the frequency or the mass.



6. What is the distance *L* between the two end points in your case? It cannot be shorten than 95 cm, if so move the oscillator away from the pulley until *L* is at least 95 cm.

L = ________ (cm)

PART 1 – Constant mass, varying frequency.

We want to explore which frequencies will produce standing waves of different wavelengths.

Step 1. Connect the string oscillator to the signal generator using the two banana cables. Set the amplitude to about half way. DO NOT set it all the way to the max value as it will only result in worse data.

Step 2. Place on the hanger a mass of 200 grams for a total mass of 250 g.

Step 3. Set the frequency on the signal generator to $f_{SG} =$ 18 Hz

7. Do you see a standing wave?

Step 6. Slowly increase the frequency until you see a standing wave.

8. How many loops are present?

9. Measure its wavelength by using the ruler printed on the aluminum track.
Note: the wavelength corresponds to the 'width' of two loops.

$\lambda =$ __________ (m)

Step 7. Keep increasing the frequency to find others standing waves. You might have to adjust the amplitude on the signal generator as well. Measure the wavelength λ by using the ruler.

10. Use the table below to collect your data. Calculate the velocity using $v = \lambda f$ in each case.

n = number of loops	f_{SG} (Hz)	λ (m)	v = (m/s)
2			
3			
4			
5			

Analysis

11. For the case $n = 3$ use equation (3) to calculate the frequency f_{CAL}

$f_{CAL} =$__________

12. Calculated the % error between the calculate f_{CAL} and the exact value f_{SG}. This error needs to be less than 10%, if not check again your measurements and calculations.

13. Input the frequency f_{CAL} in the signal generator, what difference do you observe now?

PART 2 – Varying mass, constant frequency.

We want to explore which masses produce standing waves of different wavelengths.

Step 1. Set the frequency on the signal generator to f_{SG} = 45 Hz.

Step 2. Remove the mass hanger and attach the green (or white) plastic cup to the end of the string. Use a paper clip to connect the string with the plastic cup.

Step 3. Add 20 g weight into the cup. Use the other 'transparent' plastic cup to get some sand from the main desk. Add also some sand until you obtain a standing wave. Measure the wavelength λ and observe the corresponding number of loops n.

Step 4. Use the digital scale to measure the mass of the cup with the sand.

Step 5. Varying the mass by adding/removing weights and sand to obtain a different standing wave. With care, you can obtain a few standing waves. Do not exceed 300 g.

14. Use the table below to input your data and calculations.

n = number of loop	*m* (kg)	λ (m)	λ^2 (m^2)
6			
5			
4			
3			

Analysis

Turn off the signal generator. Use your data to verify equation (2). A good way to do this is to plot λ^2 versus m and show that the plot is a straight line. Use Excel.

15. Do a linear fit of the plot of λ^2 versus m (m on the x-axis) and find the slope.

slope =________ (numerical value from the fit)

16. Write the equation which expresses the slope in terms of g, f and μ. (refer to Eq 2).

slope = (write the equation)

17. Print and submit a copy of your plot.

18. Calculate the linear mass density μ of the string using the numerical value of the slope.

μ = _______ g/m

19. Calculate the percentage difference with the given value of μ.

% difference = _____

20. The elasticity of the string is main source of error to determine μ. Explain: