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Experiment 1.10: Standing Waves on Strings

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I. EXPERIMENT 1.10: STANDING WAVES ON STRINGS

A. Abstract

Waves on a string under tension and fixed at both ends result in well-defined modes of vibration with a spectrum of frequencies given by the formula below

B. Formulas

$$f_n = n\left(\frac{v}{2L}\right), \; n = 1, 2, 3, \ldots \tag{1}$$

$$v = \sqrt{\frac{T}{\mu}} \tag{2}$$

where f_n is the frequency of the n^{th} standing wave mode on the string of length L, linear mass density μ, and under tension T, and v is the wave speed on the string.

C. Description and Background

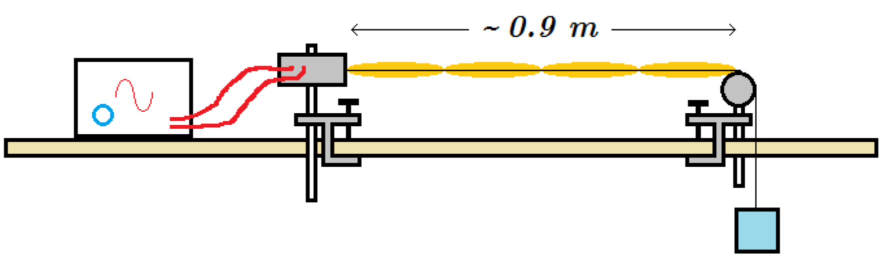

FIG. 1. Standing wave set-up.

The figure above shows the experimental set-up. An electro-mechanical device vibrates the end of a string of length, L, under tension. The tension is created by a weight, $T = Mg$, hanging over a pulley. The frequency of vibration is adjusted until an identifiable mode of standing wave is realized. In the figure, the mode has $n = 4$ anti-nodes (locations of large amplitude). In the experiment, this parameter will be fixed.

A sample segment of length, ℓ, and mass, m, is used to determine the linear mass density of the string, $\mu = m/\ell$. By combining Eqs. (1) and (2), one can derive the following relation between f_n^2 and M

$$f_n^2 = \frac{n^2 g}{4\mu L^2} M \tag{3}$$

In the experiment, the hanging mass is varied, and the frequency associated with $n = 4$ anti-nodes is determined experimentally. The data collected can then be analyzed. If the procedure is repeated numerous times, a linear regression analysis can be done and the slope, ς, of the best fit line to f_n^2 *vs.* M will equal

$$\varsigma = \frac{n^2 g}{4\mu L^2} = \frac{4g}{\mu L^2} \tag{4}$$

Because of the presence of g in this equation, it provides an indirect method of determining the acceleration due to gravity.

D. Procedure

1. Measure the length, ℓ, and mass, m, of a sample piece of string from the experiment.

2. Measure the length of the string (from vibrator to pulley), L, used to support the standing waves.

3. Attach a weight to the end of the string that hangs over the pulley.and record its mass, M, in the measurement table.

4. Adjust the frequency of the sine wave generator so that a standing wave is set up with $n = 4$ anti-nodes. Record this frequency (f_n) in the measurement table.

5. Repeat steps 3 and 4 four more times with other weights.

E. Measurements

sample string mass, m [$gram$]	
sample string length, ℓ [cm]	

length of string under tension, $L =$ ______[cm]		
Trial	M $[gram]$	f_4 $[Hz]$
1		
2		
3		
4		
5		

F. Instructions

1. Calculate the linear mass density of the string sample, μ.

2. Use the data and the equation for g implied by (4),

$$g = \frac{\mu L^2 f_4^2}{4M}$$

   to complete the Plotting Table.

3. Use the Excel file provided, **StandingWavesLabPlot**, to plot $f_4^2\ vs. M$ (include the point $(0, 0)$ in the plot), and submit the plot as part of your work.

4. Use the slope, ς, of the regression line to determine the acceleration due to gravity, g_{slope}.

5. Based on the results in the table, what is $\bar{g}$?

6. Determine the associated standard error, $\delta\bar{g}$.

7. What is the percent difference between $\bar{g}$ and g_{slope}?

8. During the semester, you have performed four experiments that either determined the acceleration due to gravity or whose results could have been used to determine it: The sphere drop, the inclined air-track and glider, the pendulum, and now standing waves on a string. Compare these four methods and make a case for which one is optimal if you conclude there is such a one.

G. Calculations

Plotting Table		
M [kg]	f_4^2 [Hz^2]	g [m/s^2]
0	0	N/A

$\mu = m/\ell$ [kg/m]	
f_4^2 *vs.* M: slope, ς [Hz^2/kg]	
g_{slope} [m/s^2]	
$\bar{g}$ [m/s^2]	
$\delta\bar{g}$ [m/s^2]	
%-Diff ($\bar{g}, g_{slope}$)	

Answer to 8 above: