

PHY 123 Lab 8 - Standing Waves

The purpose of this lab is to study standing waves on a vibrating string.

Important! You need to print out the 2 page worksheet you find by clicking on this link and bring it with you to your lab session. [<http://www.ic.sunysb.edu/Class/phy122ps/labs/dokuwiki/pdfs/lab8worksheet.pdf>]

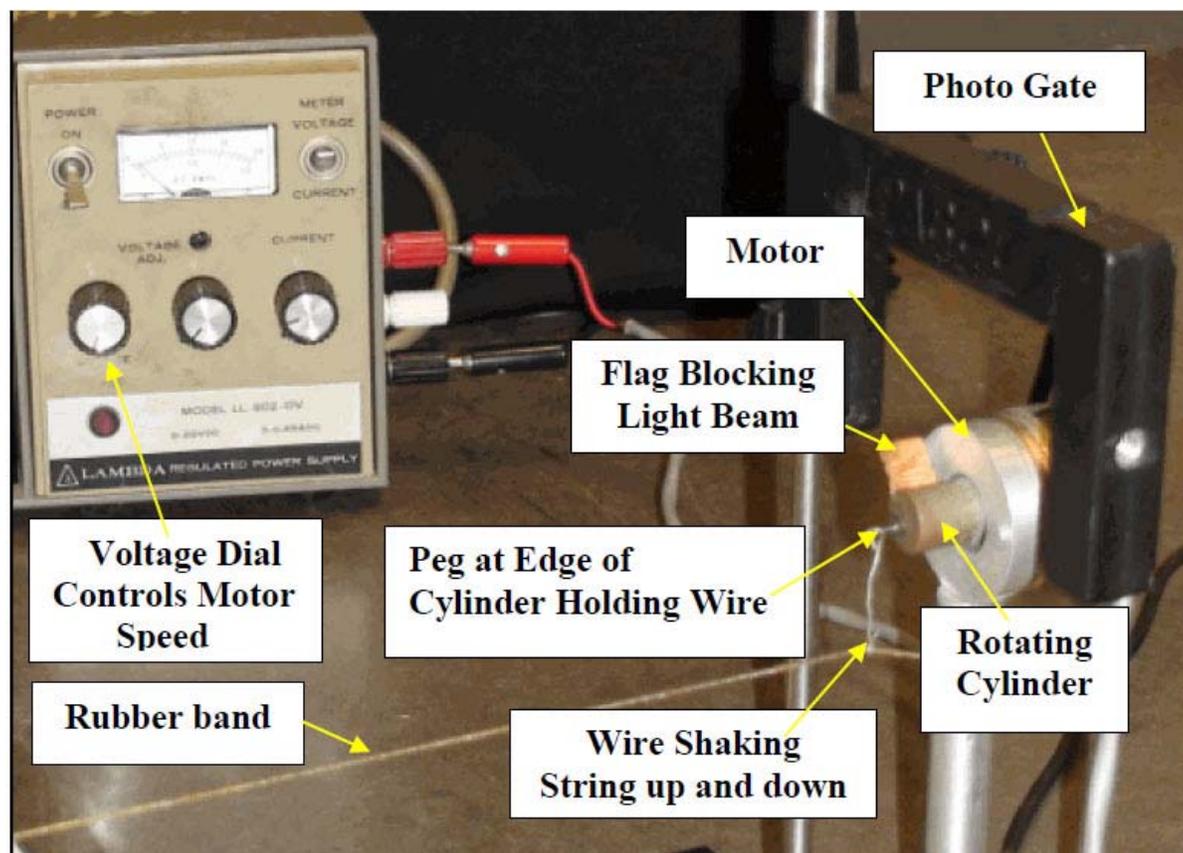
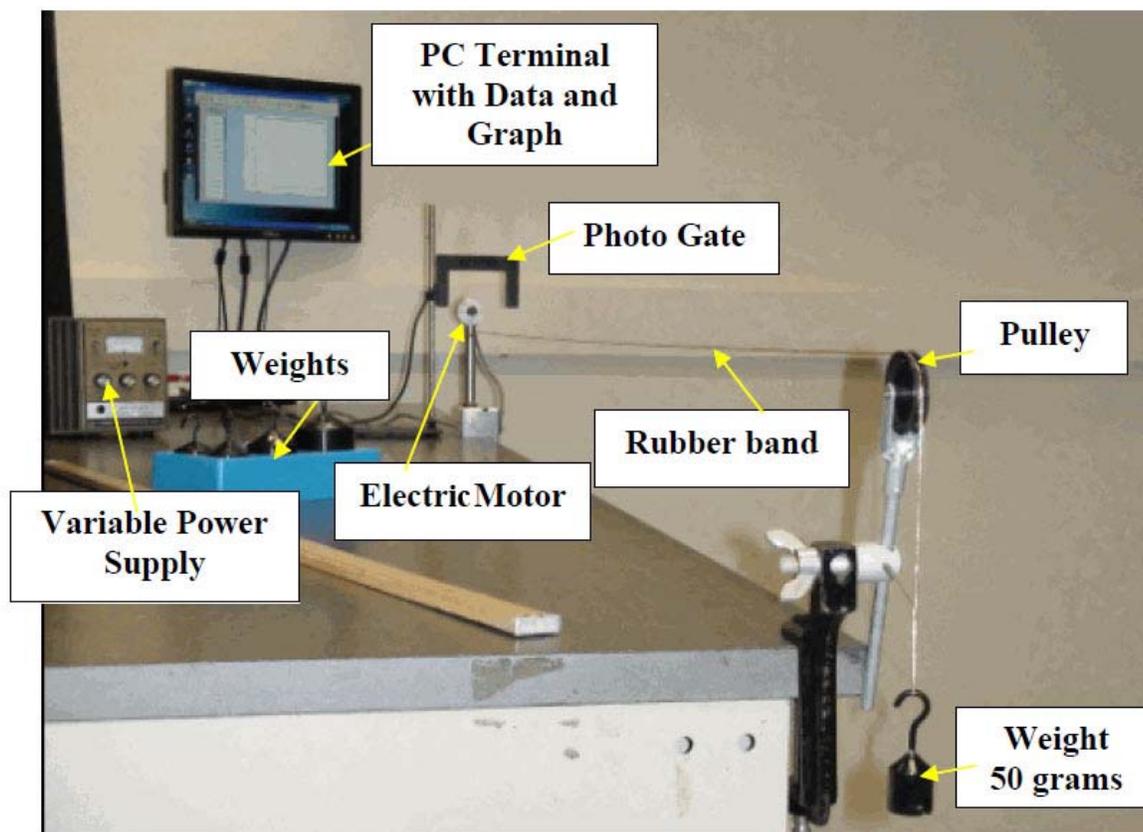
If you need the .pdf version of these instructions you can get them here [<http://www.ic.sunysb.edu/Class/phy122ps/labs/dokuwiki/pdfs/phy123lab8.pdf>].

Video

Equipment

- electric motor with flag blocking the photo gate beam once per turn
- photo gate connected to the interface box
- variable power supply controls motor speed
- rubber band, thin gold (your vibrating "string")
- pulley
- ruler
- box with weights
- a roll of thick white non-stretching string

- scale to weigh the string



Introduction

In this lab you will study standing waves on a string. You will determine what the travelling wave velocity should be from the properties of a rubber band. Then you will excite standing waves on this band, deduce the travelling wave velocity from them and compare. You then replace the rubber band by a non-stretching string and investigate the dependence of the wave velocity on the tension in the string and measure the gravitational acceleration g .

Part I: Determination of the Traveling Wave Velocity from the Tension and Linear Mass Density

In this part you will calculate the travelling wave velocity v from the tension T in a rubber band and its linear mass density μ .

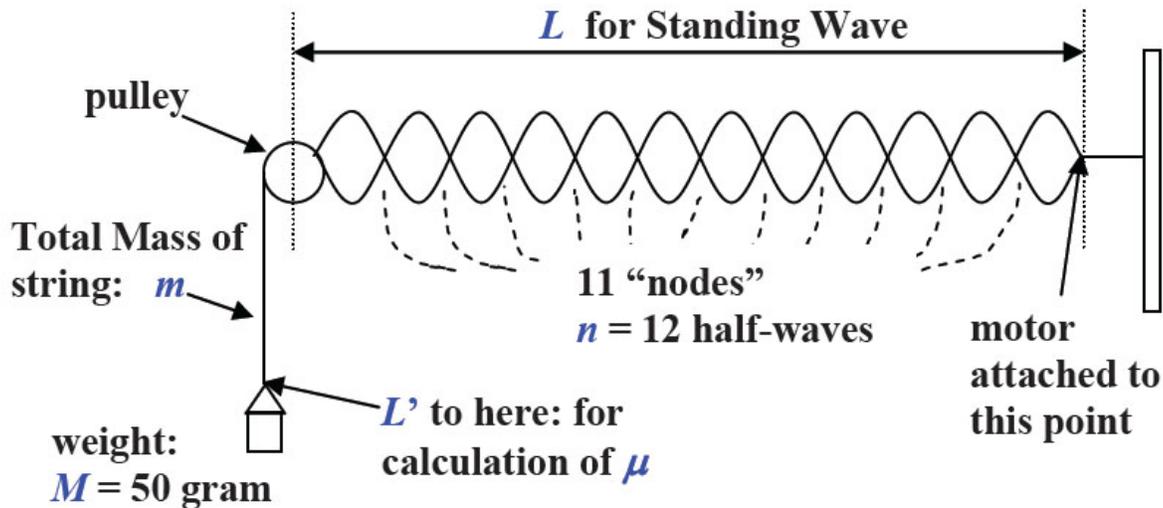


Fig 2.

The equation for the velocity of a travelling wave on a string is

$$v = \sqrt{\frac{T}{\mu}} \quad (8.1)$$

The linear mass density μ for the system above can be found using

$$\mu = \frac{m}{L} \quad (8.2)$$

and the the tension in the string will be given by the gravitational force

$$T = Mg \quad (8.3)$$

Determine the mass m and the length L' of the rubber band **while it is under tension** with a suspended weight of $M = 50$ grams. Assign an absolute error of 0.1 gram to m and an absolute error of 1 cm to L' (which accounts for loops or knots in the string). Enter your values into the table on your worksheet.

Calculate the values of T and μ and enter these on your worksheet. The largest relative error is in the length of the string, therefore (from equation 1.7 of Lab 1) we can approximate the relative error in μ to be the same as the relative error in L' .

$$\frac{\Delta\mu}{\mu} = \frac{\Delta L'}{L'} \quad (8.4)$$

Use this to calculate the absolute error in μ and write that on your worksheet as well.

Calculate the value of the travelling wave velocity v on the rubber band and enter it on your worksheet. In calculating the error in our velocity we can neglect the error in the tension, because the relative error in the tension is much less than the relative error in μ . Using equation (1.8) of Lab 1 we can say that

$$\frac{\Delta v}{v} = \frac{1}{2} \frac{\Delta\mu}{\mu} \quad (8.5)$$

Use this to find the relative error, and then the absolute error in v which you should record on your worksheet.

Part II Measurement of the Traveling Wave Velocity Using the Frequencies of the Observed Standing Waves on the Rubber Band

In this part you excite standing waves on the rubber band at resonance frequencies f_n (n is the number of half waves fitting into the string – see the Figure above) and deduce from a graph of f_n vs n the travelling wave velocity, comparing it the value you obtained in Part I.

The equation for the frequencies f_n of the standing waves on a string is:

$$f_n = n \frac{v}{2L} \quad (8.6)$$

We can see that this equation has the form $f_n = [\dots] n$. The term $[\dots]$ is the slope k of the corresponding linear graph we should obtain if we plotting f_n vs n .

The rubber band is strung over a pulley from which the weight is suspended. A small electric motor on the other end of the band is driven by a variable power supply and provides the oscillatory driving

force, which generates a traveling wave on the band. The wave is reflected back along the string at the pulley, and is reflected again at the vibrator. When the second reflected wave is in phase with the original wave, a standing wave pattern will be observed on the string as sketched in Fig. 2 above. The distance between the nodes of the standing wave is one-half of the wavelength of the wave. "Nodes" are points of destructive interference where the rubber band remains still and anti-nodes are points of constructive interference where the band oscillates with maximum amplitude. Sketch on the grid on your worksheet a standing wave pattern for a wave with several half-waves fitting into the length L. Label it with the number of half-waves, nodes and the length of the rubber band.

Measure the length L (see Fig 2 above) with the ruler, estimate its error and enter both on your worksheet. (Note that this is not the same as L' which we measured earlier!)

Get your computer and photo gate ready for data taking:

- Place the motor in the photo gate such that the flag attached to the cylinder in the center of the motor blocks the light beam of the photo gate when the flag is raised.
- Connect the photo gate output to the interface box by plugging its cable into the top socket (labeled "DIG/SONIC 1") of the black interface box ("LabPro").
- Turn on the computer and check the system by following these instructions: Double click the icon "Exp8_Period". A window with a spreadsheet on the left (having "State, Pulse Time" columns and a graph labelled "Pulse Time") comes up. On top is a window "Sensor Confirmation".
- Click "Connect", again "Connect".
- Test the photo gate: block the photogate beam with your finger and see the red light on the cross bar of the photogate turn on.
- Click OK.

You are ready for data taking now.

Vary the frequency of the driving motor by varying the voltage from the power supply and observe standing waves as sketched in Fig. 2, whenever the driving frequency is equal to a frequency, which obeys equation 8.6, the allowed resonance frequencies of the rubber band under tension. Once you have a stable pattern click the green icon "Collect" on the PC screen and take a few measurements.

The times you see on the PC screen on the left are measured periods of a motor revolution. The frequency with which the rubber band is shaken is the reciprocal of the period ($f = \frac{1}{T}$). You see on the right a horizontal line, since all periods are equal as time goes on.

Establish at least 7 consecutive resonance frequencies f_n and enter the values of 7 of them, together with the number of half waves n on the table in your worksheet. Use the plotting tool below to plot f_n vs n (no errors required). You should check the box that asks if you the fit goes through (0,0). (Think about why!)

x axis label (include units):

y axis label (include units):

Check this box if the fit should go through (0,0).
 (Don't include (0,0) in your list of points below, it will mess up the fit.)

What kind of errors are you entering below? None

x1: <input style="width: 80px;" type="text"/> +/- <input style="width: 80px;" type="text"/>	y1: <input style="width: 80px;" type="text"/> +/- <input style="width: 80px;" type="text"/>
x2: <input style="width: 80px;" type="text"/> +/- <input style="width: 80px;" type="text"/>	y2: <input style="width: 80px;" type="text"/> +/- <input style="width: 80px;" type="text"/>
x3: <input style="width: 80px;" type="text"/> +/- <input style="width: 80px;" type="text"/>	y3: <input style="width: 80px;" type="text"/> +/- <input style="width: 80px;" type="text"/>
x4: <input style="width: 80px;" type="text"/> +/- <input style="width: 80px;" type="text"/>	y4: <input style="width: 80px;" type="text"/> +/- <input style="width: 80px;" type="text"/>
x5: <input style="width: 80px;" type="text"/> +/- <input style="width: 80px;" type="text"/>	y5: <input style="width: 80px;" type="text"/> +/- <input style="width: 80px;" type="text"/>

x6:	<input type="text"/>	+/-	<input type="text"/>	y6:	<input type="text"/>	+/-	<input type="text"/>
x7:	<input type="text"/>	+/-	<input type="text"/>	y7:	<input type="text"/>	+/-	<input type="text"/>
x8:	<input type="text"/>	+/-	<input type="text"/>	y8:	<input type="text"/>	+/-	<input type="text"/>
x9:	<input type="text"/>	+/-	<input type="text"/>	y9:	<input type="text"/>	+/-	<input type="text"/>

submit

Record the value of the slope k and it's error on your worksheet. Use it to calculate the velocity v (using $k = \frac{v}{2L}$). Calculate the error in v from the error in L and the error in the slope using (1.7) of Lab 1.

Are the two values you obtained for v the same within error?

Part III Verification of the Dependence of the Traveling Wave Velocity on the String Tension T and a Measurement of the Acceleration of Gravity g :

In this part you will measure the dependence of the frequencies f_n on the tension T in a non-stretching string. You vary the tension by suspending various weights of mass M from the string. You should keep the number of half waves fixed at $n = 3$.

By combining equations (8.1), (8.3) and (8.6) you can obtain an equation for the frequency f_3 as a function of the mass M that has is hung from it.

$$f_3^2 = \frac{3^2}{(2L)^2} \frac{g}{\mu} M$$

(8.7)

Replace the "rubbery" string with the thick white string. The string does not stretch noticeably when put under tension, thus having a fixed linear mass density for various tensions. Determine its linear mass density μ as you did for the rubber band in Part I.

Vary the tension T by suspending masses $M = 50, 100, 150, 200$ grams. Measure the frequencies f_3 for the standing wave with 3 half – waves for each mass M and enter them with their squares (ie as f_3^2) in the table on your worksheet.

Graph f_3^2 vs M using the tool below (no errors). You should check the box that asks if you the fit goes through (0,0).

x axis label (include units):

y axis label (include units):

Check this box if the fit should go through (0,0).

(Don't include (0,0) in your list of points below, it will mess up the fit.)

What kind of errors are you entering below?

x1:	<input type="text"/>	+/-	<input type="text"/>	y1:	<input type="text"/>	+/-	<input type="text"/>
x2:	<input type="text"/>	+/-	<input type="text"/>	y2:	<input type="text"/>	+/-	<input type="text"/>
x3:	<input type="text"/>	+/-	<input type="text"/>	y3:	<input type="text"/>	+/-	<input type="text"/>
x4:	<input type="text"/>	+/-	<input type="text"/>	y4:	<input type="text"/>	+/-	<input type="text"/>

x5:	<input type="text"/>	+/-	<input type="text"/>	y5:	<input type="text"/>	+/-	<input type="text"/>
x6:	<input type="text"/>	+/-	<input type="text"/>	y6:	<input type="text"/>	+/-	<input type="text"/>
x7:	<input type="text"/>	+/-	<input type="text"/>	y7:	<input type="text"/>	+/-	<input type="text"/>
x8:	<input type="text"/>	+/-	<input type="text"/>	y8:	<input type="text"/>	+/-	<input type="text"/>
x9:	<input type="text"/>	+/-	<input type="text"/>	y9:	<input type="text"/>	+/-	<input type="text"/>

Write down the slope of the graph k and its error. Use this to calculate g the acceleration due to gravity (From equation (8.7), $k = \frac{3^2}{(2L)^2} \frac{g}{\mu}$). To calculate the error in your measurement of g we neglect the error in L and use the fact that the relative error in g will be due to the relative error in the slope, $\frac{\Delta k}{k}$, and the relative error in μ , $\frac{\Delta \mu}{\mu}$ and from equation (1.7) of Lab 1 will be

$$\frac{\Delta g}{g} = \sqrt{\left(\frac{\Delta k}{k}\right)^2 + \left(\frac{\Delta \mu}{\mu}\right)^2}.$$

Once you have your value for g and its error compare it to the established value. Is it consistent with that?

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