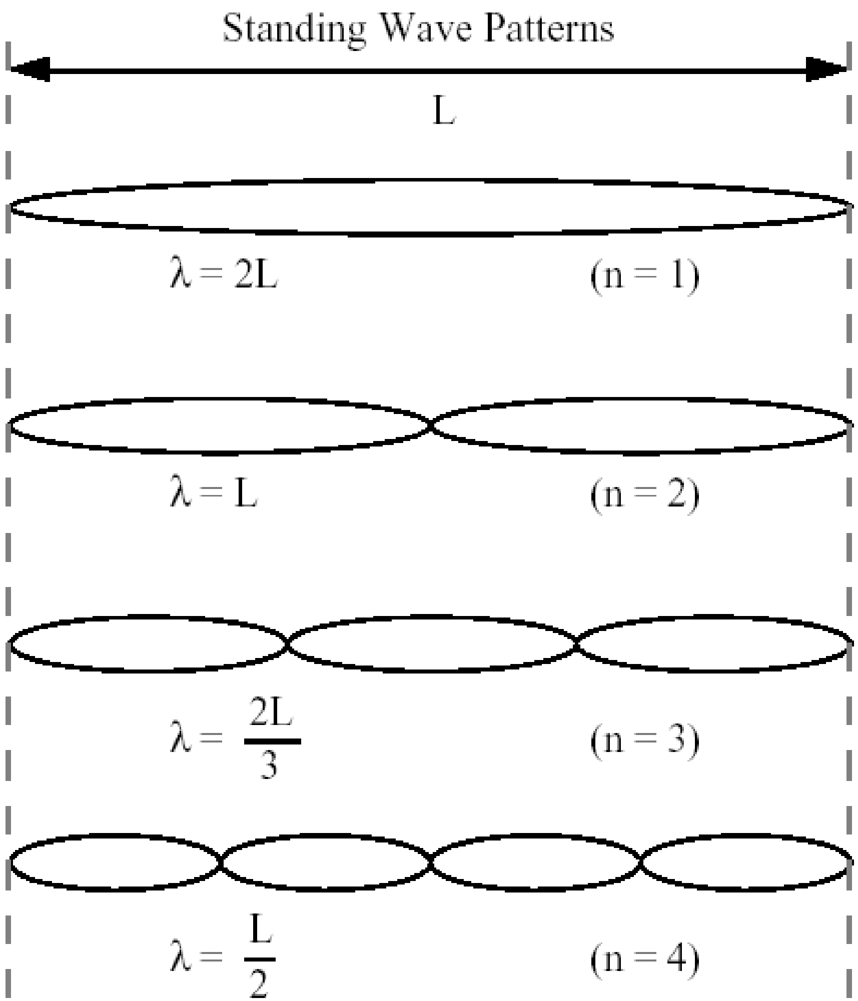
PHYS 275 – Experiment 8
Standing Waves on a String

Experiment Summary

- Today we will study oscillations in a string under tension
  - The physics is a bit more complicate than last weeks: we will study standing waves
  - The experimental apparatus consists of a string under tension (a weight is applied to it); we will measure the frequency of its oscillations
- Technical topic of the week: weighed averages
  - We will combine measurements using weights, which will allow us to improve the precision of our estimate of the quantity of interest

Standing-waves Theory



- Standing (or stationary) waves are distinguished using their <u>mode number n</u>
  - Node = location where the amplitude is zero
  - Mode number n = number of nodes + 1
  - Wavelength $\lambda = 2L/n$

More Theory

- The speed and frequency of a standing wave are related:
  - $v_s = \lambda f = \sqrt{\frac{T}{\mu}}$
    - T is the tension of the string, measured in Newton
    - μ is the linear mass density of the string (mass/length), measured in kg/m
    - λ is the wavelength, $\lambda = \frac{2L}{n}$
    - f is the wave frequency, measured in …
    - v_s is the wave speed

This is a form of *dispersion relation*

$$\Rightarrow \frac{f_n}{n} = \left[\frac{1}{2L\sqrt{\mu}}\right] T^{1/2}$$

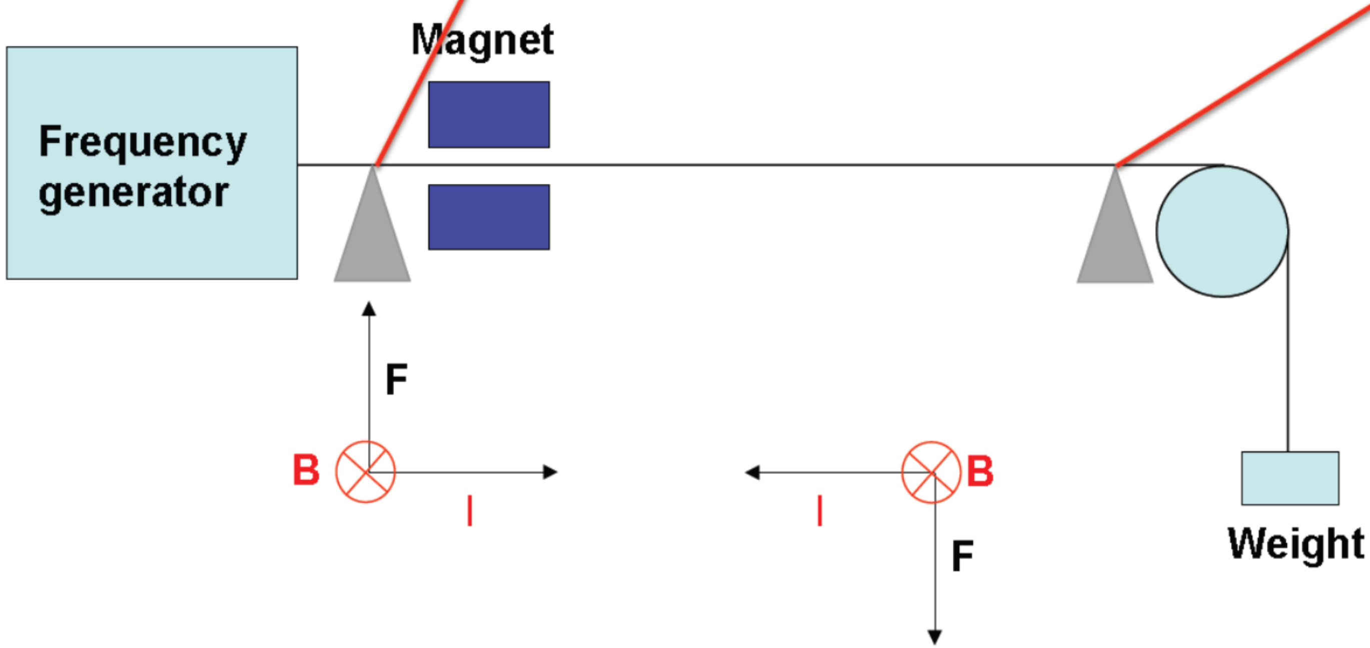
Measurements

- We will measure the frequency corresponding to different modes, and combine these measurements to obtain the best estimate of the linear mass density
  - The idea is that when you combine measurements with different precision, you want to give more weight to the more precise ones
- Here are the main formulae
  - Let us assume that we have the measurements $(x_1, \sigma_1), (x_2, \sigma_2), \ldots, (x_n, \sigma_n)$
  - We take the weight of each measurement to be $w_i = \frac{1}{\sigma_i^2}$
  - Finally: $\langle x \rangle = \frac{\sum_{i=1}^{n} w_i x_i}{\sum_{i=1}^{n} w_i} = \frac{\sum_{i=1}^{n} x_i / \sigma_i^2}{\sum_{i=1}^{n} 1 / \sigma_i^2}$; $\sigma_{\langle x \rangle} = \frac{1}{\sqrt{\sum_{i=1}^{n} w_i}} = \frac{1}{\sqrt{\sum_{i=1}^{n} 1 / \sigma_i^2}}$

Experimental Apparatus

Variable frequency & tension standing wave setup:

Frequency generator;
Permanent magnet;
string; meter stick;
weight holder; slotted weights;

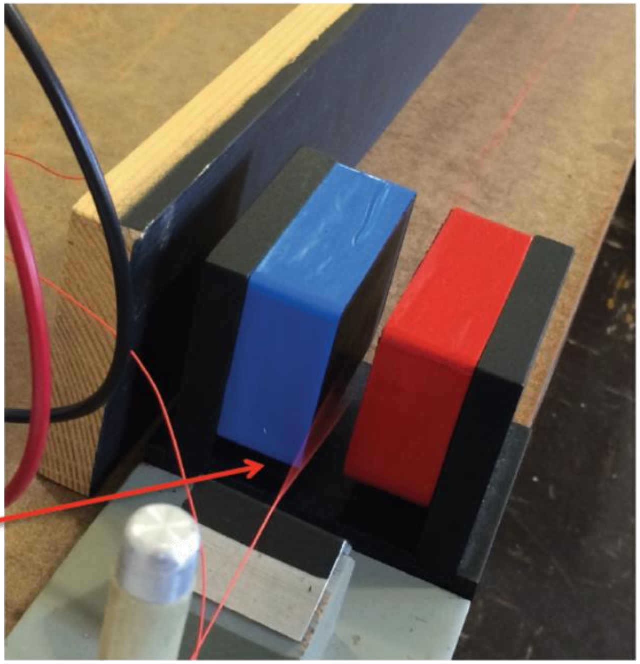


Some Suggestions

Use this meter to read frequency

Don’t peel off this black tape. Frequency reading from this panel is not accurate

Be careful. This resistor can become very hot!



Adjust magnet position and current amplitude to make sure string doesn’t touch magnet

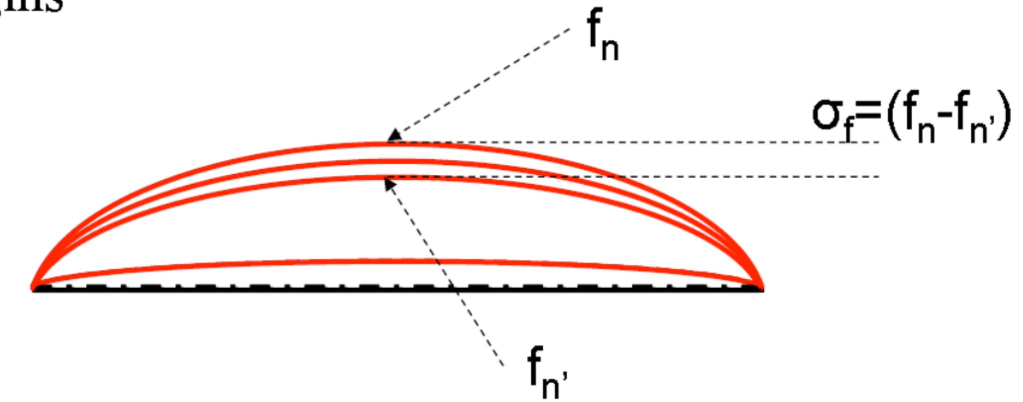
More Suggestions

· mass density, μ

$\mu = M/L$

We have sample string for you to measure mass density. – everyone needs to measure mass of sample string; L=2.0000 ± 0.0003m

· Determine the uncertainty of f_n: (1) the difference between the resonant frequency and the frequency at which the rapid increase in amplitude begins



or (2) measure frequency for a few times and calculate standard deviation as uncertainty.

· pay attention to UNITS

(Yet) More Suggestions

- Calculation of weight and tension: need to remember to **plus the mass of the holder.** Alternatively, my suggestion is to bring your mass with mass holder and to measure together by scale

- Vertical mode standing wave: try to decrease the amplitude; but if you still can not get rid of circular mode, please don't worry- you can simply take it as systematic error.

- Calculation of weighted (f_n/n): I will suggest making a table to calculate all the components you need for weighted mean:

n	f_n	f_i	$\sigma(f_n)$	(f_n/n)	$\sigma(f_n/n)$	$w_\text{n}=1/\sigma^2$	$[(\text{f}_\text{n}/\text{n})]\bullet w_\text{n}$
1							
…							
						$\sum_n w_n$	$\sum_n [(f_n/n)\bullet w_n]$

Notes and Reminders

- Submit your Excel spreadsheet on ELMS and turn in your check sheet <u>before</u> leaving the lab
- Complete the final version of your report by 1pm next week
- Finish the homework set in Expert-TA by 2pm next week
- Turn off your equipment and clean up your bench area before leaving the classroom
- <u>Save your data on the local disk frequently!</u>