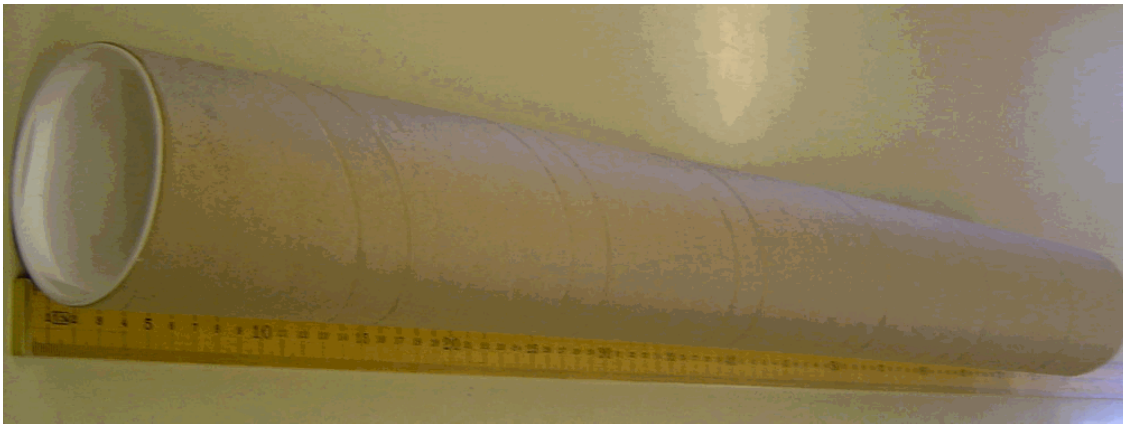
Standing waves

Objectives

In this experiment our objective is to investigate the sound that arises when the lid of a cardboard tube is hit with a finger. The sound is picked up by a microphone connected to a CBL or a LabPro. Collected data will be stored in a graphing calculator and can be analysed either with the calculator or a computer.

Materials

Cardboard tube, open in one end and sealed with a plastic lid at the other, Vernier Microphone Probe, CBL or LabPro and TI-83 or TI-84.



Procedure

Before setting up the experiment make sure that you have the program MIC in your calculator. If not, download from the LEPLA site.

Connect the microphone probe to the CBL (CH1). Also connect the CBL to the calculator.

Arrange your experimental setup so that the open end of the tube is close to the microphone and points towards it.

Start the program MIC. Smash the lid of the cardboard tube with your index finger. The program triggers data sampling when the signal arrives.

When the experiment is finished the calculator screen will show a graph. The y-axis shows the sound intensity by means of a signal in volts. The x-axis is the time in seconds. Voltages are stored in list L_2 and time data in list L_1.

If you are unable to perform the experiment there are files set up so that you can study the experiment and analyse previously collected data. Your options are shown below:

Download previously collected data.

View a short movie showing the experiment

Analysis

To go to the analysis section choose one of the options below

Data analysis using TI83 or TI83 Plus (your own or downloaded data)

Data analysis using Excel

Standing waves - Analysis using TI83/TI84

If you have any problems handling the graphing calculator help is available using the links that are underlined and highlighted in blue.

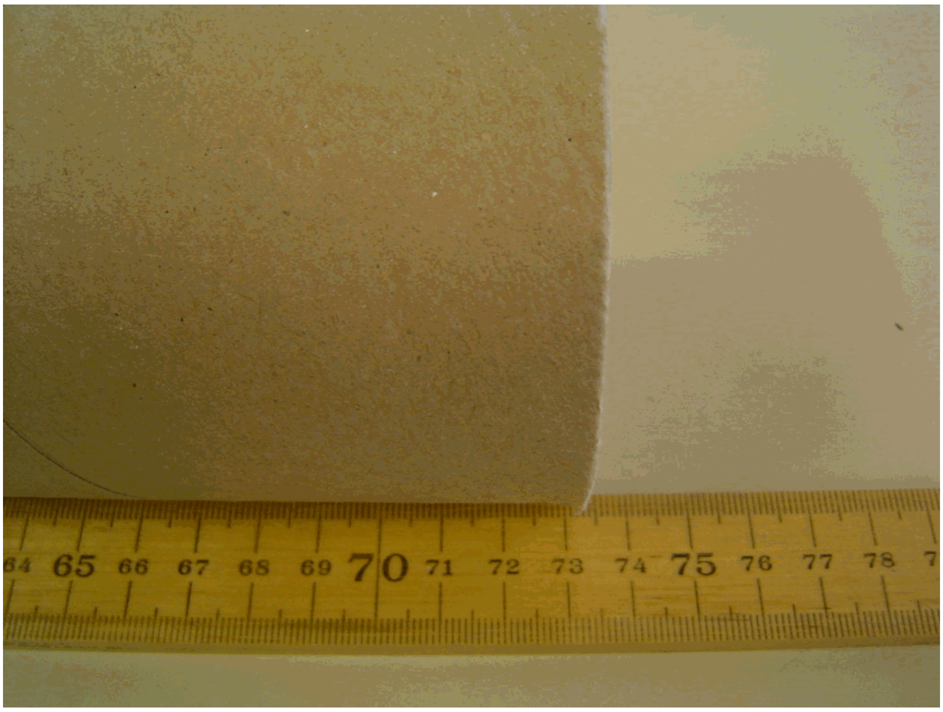
If you are analysing your own experimental data disregard the following section.

Download the data file TUBE to your calculator.

Time data (unit s) is in list L1 and voltage, sound intensity data, in list L2.

Graph voltage versus time.

The length of the tube must be known if you want to verify the theory for standing waves in a half-open tube from this experiment. The length can be found from the picture.



Study the graph. Does it look as expected? Try to explain the overall behaviour of it. If you need a hint click here!

Identify maximas and use them to calculate the period of the fundamental oscillation of the air column in the tube.

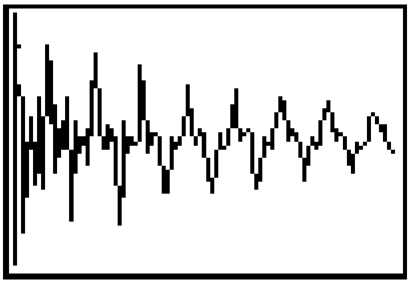
Calculate the wavelength of the fundamental oscillation of the air column. Use this and the tube length to find a value of the speed of sound.

Is this value in agreement with the theoretical value, i.e. does the experiment verify the theory for standing waves?

When you have finished your work, **but not before**, you can compare your conclusions with the completed analysis.

Standing waves - Completed analysis using TI83/TI84

When the experiment is done the following graph is found in the calculator window, if you did use downloaded data. With a dataset of your own minor differences can appear.

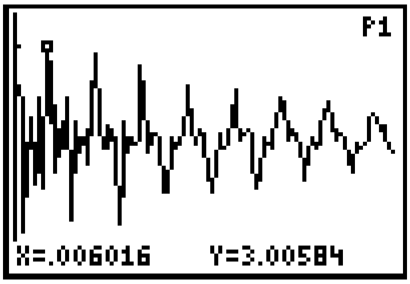


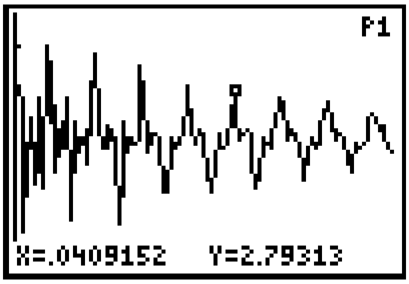
When the index finger hits the lid a travelling pressure wave starts from that end of the tube travelling towards the mouth of the tube where it is partially reflected. Back to where everything started the sound wave is reflected towards the lid, and so on. There will be a superposition of the outgoing and reflected waves resulting in a standing wave in the air column of the tube. The amplitude is damped as a result of energy loss from the air column due to the part of the sound wave that is not reflected at every reflection against the mouth and the lid.

The superposition of the incoming and reflected waves gives a standing wave as a result. The standing wave will have a node in one end and an antinode at the other end of the column. This is the first harmonic or fundamental oscillation of the air column of the tube. This mode of oscillation is the one with the longest wavelength. Other modes are possible with more nodes in the column but the important thing is that only certain frequencies are possible. Those frequencies mainly depend on the length of the air column, ie. the length of the tube. You can see the perturbation from other modes, second harmonic in particular as a result of the "non-sine" behaviour of the signal. There is a superposition of higher modes in the curve.

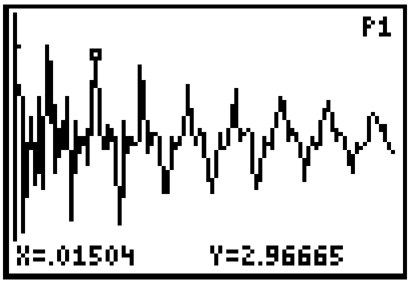
Using the principal maxima belonging to the fist harmonic we can now find the period of this oscillation. Move the cursor along the graph to find the x-coordinates for the maxima.

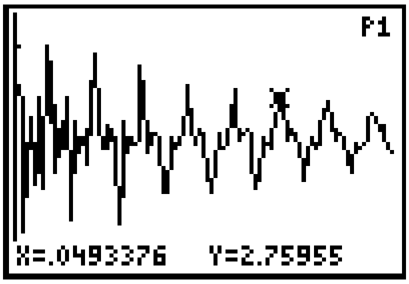
We have selected two points with four periods difference starting with the pair 0.0060 s and 0.0409 s.



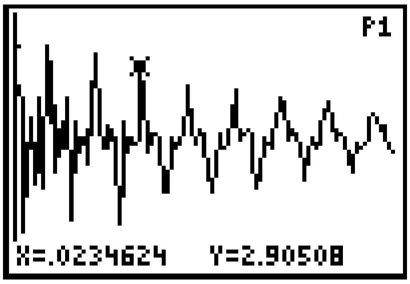


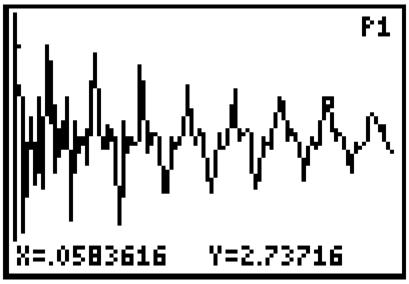
This procedure is repeated along the graph with 0.0150 s and 0.0.0493 s,



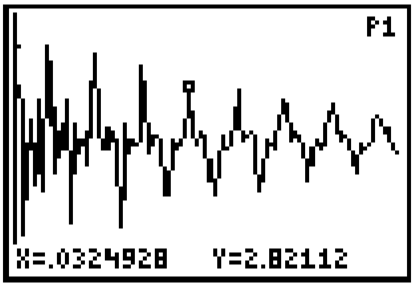


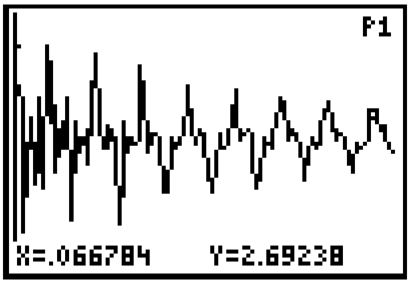
then 0.0235 s and 0.0584 s





and finally 0.325 s and 0.0668 s.





These values give us the time for four periods of 0.0349 s, 0.0343 s, 0.0349 s and 0.0343 s respectively. The mean of these values is 0.0346 s. >From this we find the period
T = 0.0346/4 s = 0.00865 s.

The frequency for the first harmonic is f = 1/T = 116 Hz.

From the photo showing the tube we get the length of the air column 0.732 m.

The wavelength of the wave can be calculated from the length of the air column of the tube. The standing wave has a node at one and an antinode and at the other end of the column. Hence the length of the tube will correspond to 1/4 of a wavelength or in other words the wavelength is 4 times the length of the tube.λ = 4*0.732 m = 2.93 m.

From these we find the velocity of the wave $v = f*\lambda$ = 116*2.93 m/s = 340 m/s

This is in good agreement with the theoretical value of the speed of sound at room temperature. This confirms our explanation of the standing wave in the air column of the tube.