"Sonic boom"

SOCRATES MINERVA Programme 99843-CP-1-2002-1-PL

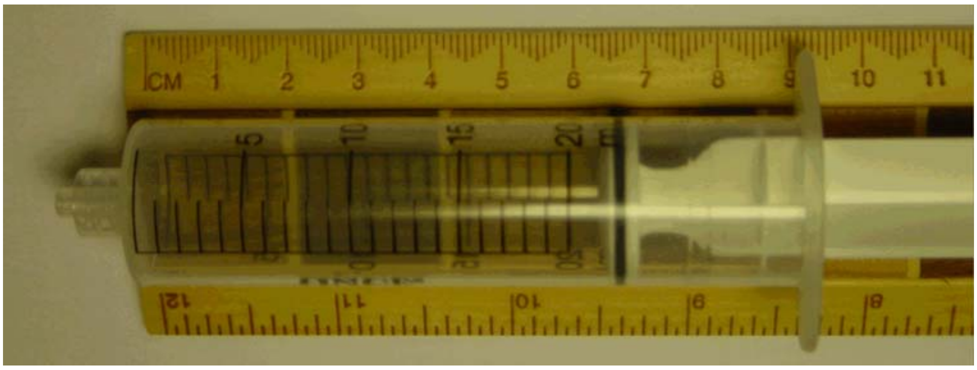
Data acquisition

Objectives:

The objective of this experiment is to explore the pressure changes that occur when a piston is pulled out of a small syringe and to explain the properties of the sound pulse.

Materials:

Pressure sensor, CBL, TI83/84 and a small syringe (20 ml).



Before setting up the experiment make sure that you have the programs SONBOOM and CLEAN in your TI-83.

Attach the syringe to the pressure sensor. Connect the sensor to Channel 1 on the CBL and CBL to the calculator.

Before running the experiment try to figure out what a pressure versus time graph will look like as the piston is pulled out rapidly.

Start the program SONBOOM on your calculator. There is a built in triggering condition in the program which means that data collection will start automatically as the pressure reaches a certain value. When the text PULL is visible on the calculator screen pull the piston out of the syringe as fast as possible. The program collects 999 data points one each 1/10 000 of a second giving a total experiment length of almost 0.1 s.

After the experiment the pressure-time-graph will be shown on the calculator. The y-axis is the pressure in kPa and the x-axis is the time in seconds. The pressure data are stored in list L_2 and the time data is stored in list L_1.

If you are unable to conduct the experiment there are files set up so that you can look at the experiment and analyse the data. Just choose from the menu below:

Look at a short video of the experiment. Get data to your TI-83/84.

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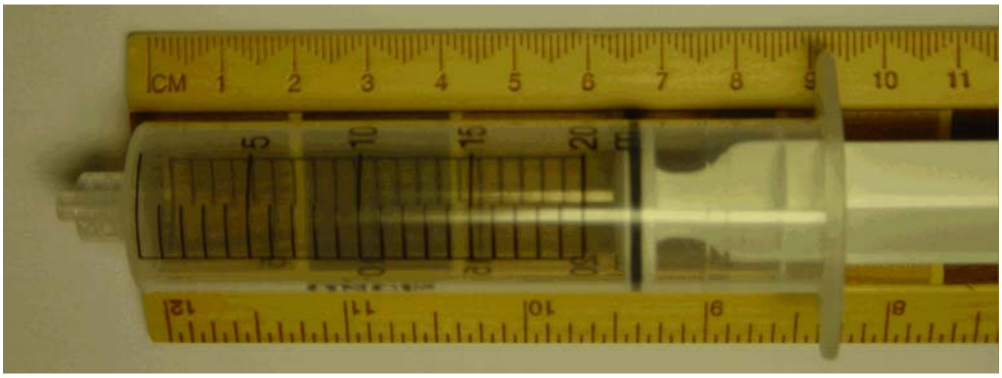
Data analysis (TI 83/TI84)

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

If you download data from the website you get to lists with pressure data in list L_2 and time data in list L_1. The length of the syringe must be known if you want to calculate the speed of sound from this experiment. The length can be found from the picture below.

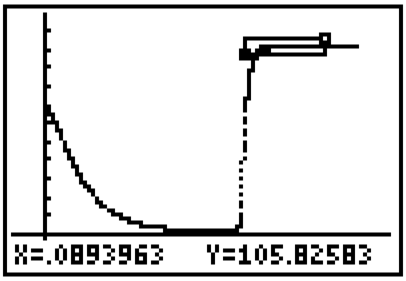


Analysis 1: Discussion of the pressure curve

Study the graph. Does it look as expected? Try to explain the over all behaviour of it..

Analysis 2: The sound from the tube

The most interesting part of the curve actually is when pressure has returned to normal. Use ZOOMBOXto zoom in the part shown below.



Try to explain why the pressure behaves as it does during this time interval. Help on how to think is available here.

Analysis 3: Calculating the speed of sound

Use the graphs from analysis 2 and the dimensions of the syringe to calculate the speed of sound.

When you have finished your work, you can compare your conclusions with the completed analysis.

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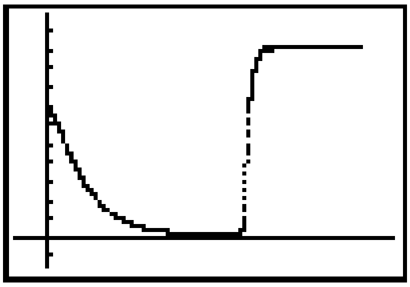
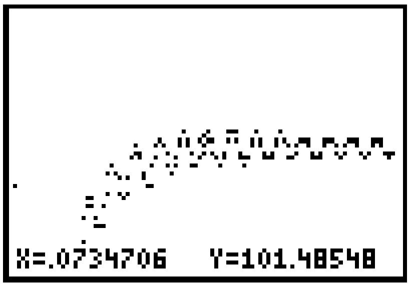
Completed analysis (TI 83/TI84)

When the experiment is done you will get a graph showing pressure as a function of time. If you use downloaded data the graph will look as follows.

Analysis 1: The pressure curve

If the piston is pulled out of the syringe as fast as possible it can be assumed that the speed of the piston is approximately the same during the experiment. This means that the increase of the volume of the trapped gas proportional to time. When the volume increases the pressure decreases (Boyles law) and hence we will get a graph where the pressure is inversely proportional to time.

The last part of the graph corresponds to the fact that the piston has left the syringe and air is running back into the syringe. The pressure returns to normal pressure of the room.

Analysis 2: The sound from the tube

If we look closer at the graph after pressure has returned to normal we see that there are some nice oscillations in pressure.

These regular pressure changes cause the sound when the piston is pulled out of the syringe.

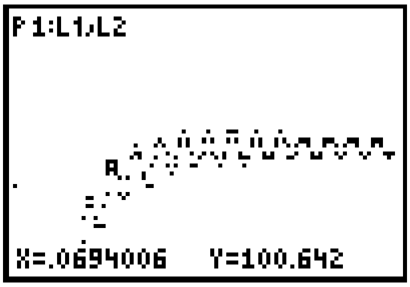
Analysis 3: The speed of sound

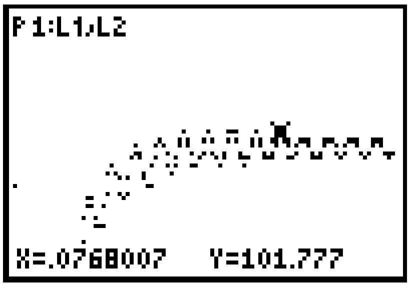
To be able to understand the oscillations we will have to know a little more about sound and standing waves.

Sound is a phenomenon that appears as a result of pressure changes in a medium, for example air. Pressure changes travel as a wave out from the source with a certain speed depending of the medium. As a result of the fast pressure changes that appear when the piston is torn out of the syringe, there will be a travelling pressure wave that is reflected at the bottom of the syringe. 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 syringe. 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 syringe.

Knowing this theory we can calculate the speed of sound.

Use TRACE to get the frequency of the oscillation. The two screen shots below give as the x-coordinates that is the time for two maximums of the pressure curve.





To get better accuracy we have chosen two points at a time distance more than one period apart. The choice is seven complete oscillations. The length of the time interval between these is 0.0768 s – 0.0694 s = 0.0074 s.

The period of the oscillation is T = 0.0074 s / 7 = 0.00106 s = 1.06 ms.

The frequency of the oscillation $f = 1/T$ = 1/0.00106 Hz = 943 Hz.

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

From the photo showing the syringe we get the length of the air column 9.1 cm.

The wavelength is: $\lambda = 4 \cdot 9.1$ cm = 36.4 cm.

Using $v = \lambda \cdot f$ we can calculate the speed of sound in air.

$v = 0.364 \cdot 943$ m/s = 340 m/s

This is in good agreement with the theoretical value at room temperature. This confirms our explanation of the sound bang as a result of the oscillations of pressure in the air column of the syringe.