Glass Bottles as Helmholtz Resonators

Asad Hussain
Nasir Siddiqui
Syed Haider Ali

Aims

- To analyze the extent to which the selected bottles act as Helmholtz Resonators according to the following equation:

$$f_0 = \frac{c}{2\pi}\sqrt{\frac{S}{V(l+\Delta l)}}$$

How we Chose the Bottles

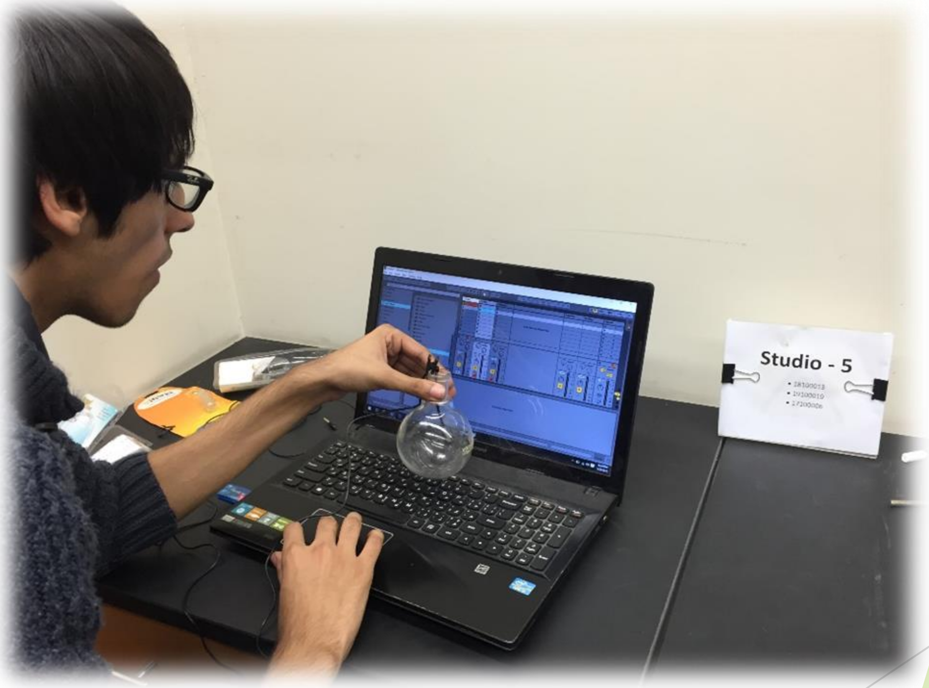
- We chose glass bottles because the compression of the walls is negligible compared to plastic bottles.
- In particular we checked their impulse response; the response was in the 4KHz range
- This shows that any additional resonance will exist in the more than 4KHz range
- Ease of availability, roughly fit the characteristics of a Helmholtz Resonator i.e defined neck and separate cavity volume.

Bottles We Chose

- Shezan Grape Juice Glass Bottle
- Murree Brewery Lemon Malt Bottle
- 250 ml Sprite Glass Bottle

Procedure 1

- Blow gently at the opening of the bottle with the tip edge pressed against your lower lip.
- Adjust angle till you hear a clear resonant frequency and record it on a laptop using Ableton.
- Isolate the resonant frequency by cutting the clip and note where the peak forms on the graph on Ableton; that is the resonant frequency
- Add a measured volume of water in the bottle using a measuring cylinder
- Repeat steps 1 through 4 for the new cavity volume and note the new frequency
- Continue the process until the cavity volume is too small to produce a resonant frequency
- For each recorded frequency, analyze the reading by sampling it with a sample size of 32768 and a sample rate of 44,000 Hz

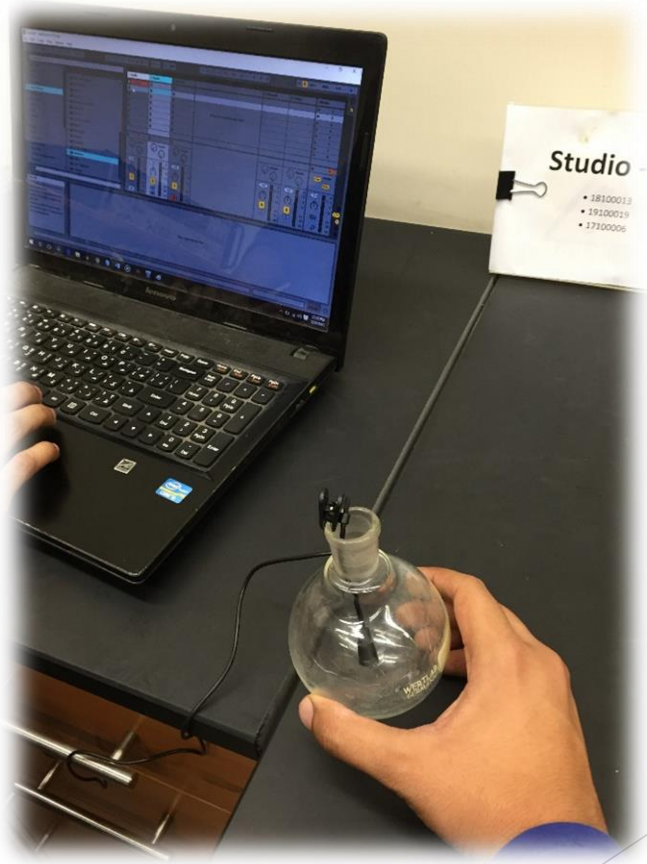


Limitations

- Effective neck length had to be determined as the bottles do not have a clear boundary between the cavity and the neck. This was achieved by sampling the water height for every small volume of water added and profiling the bottle.
- Measuring the height of the water accurately with a ruler is difficult, given the curved surface of the bottles.
- Blowing air with varying intensity changes the resonant frequency, but within acceptable bounds.

Procedure 2

- Repeat the steps taken in procedure 1 with the following additions:
  - Use a round bottom flask instead of the bottles as it is closer to the ideal Helmholtz resonator.
  - Measure the height of the water in the cylinder for each volume of water added to allow profiling of the bottle in order to determine the effective length of the neck and the boundary between the neck and the cavity.

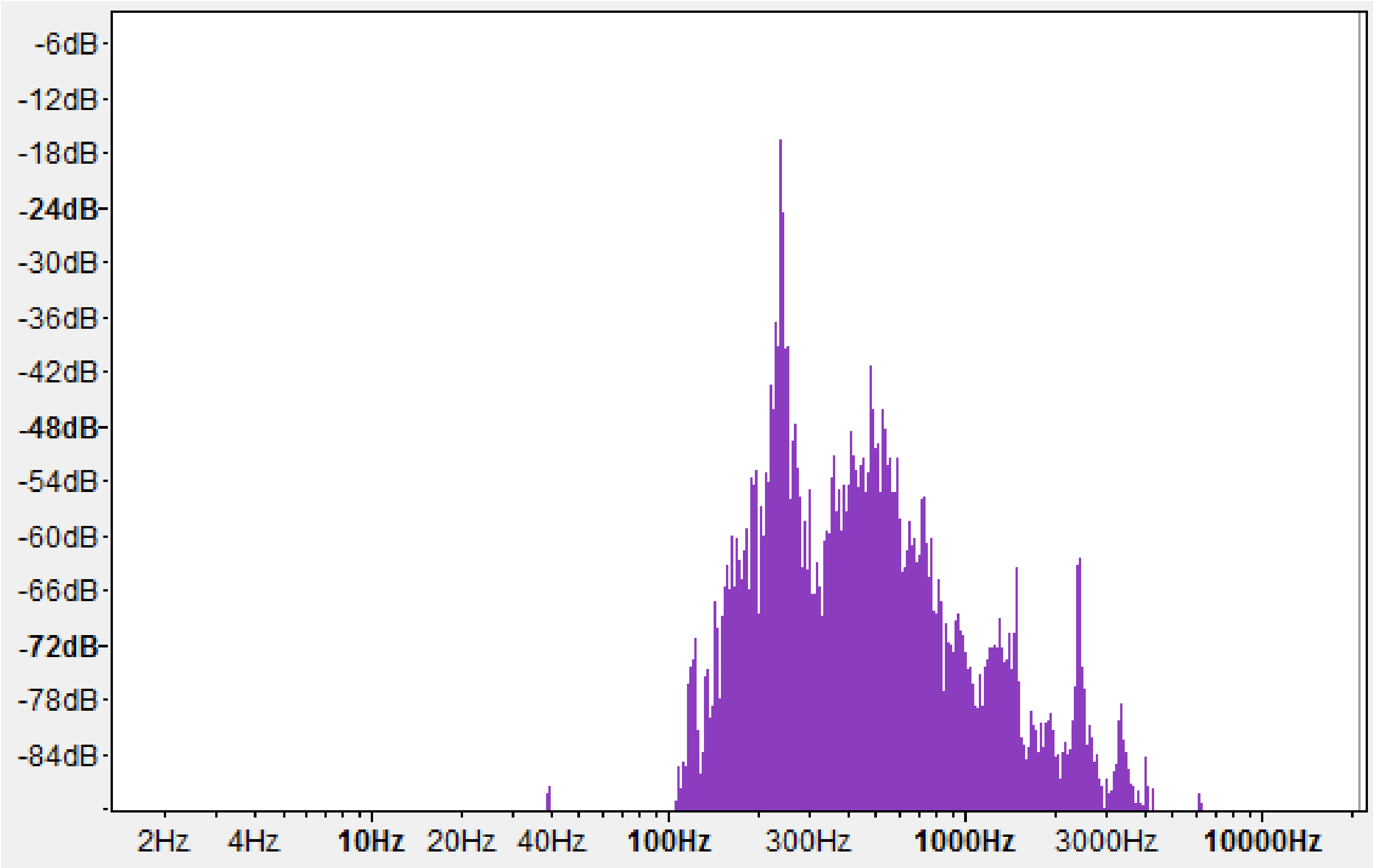


Analysis

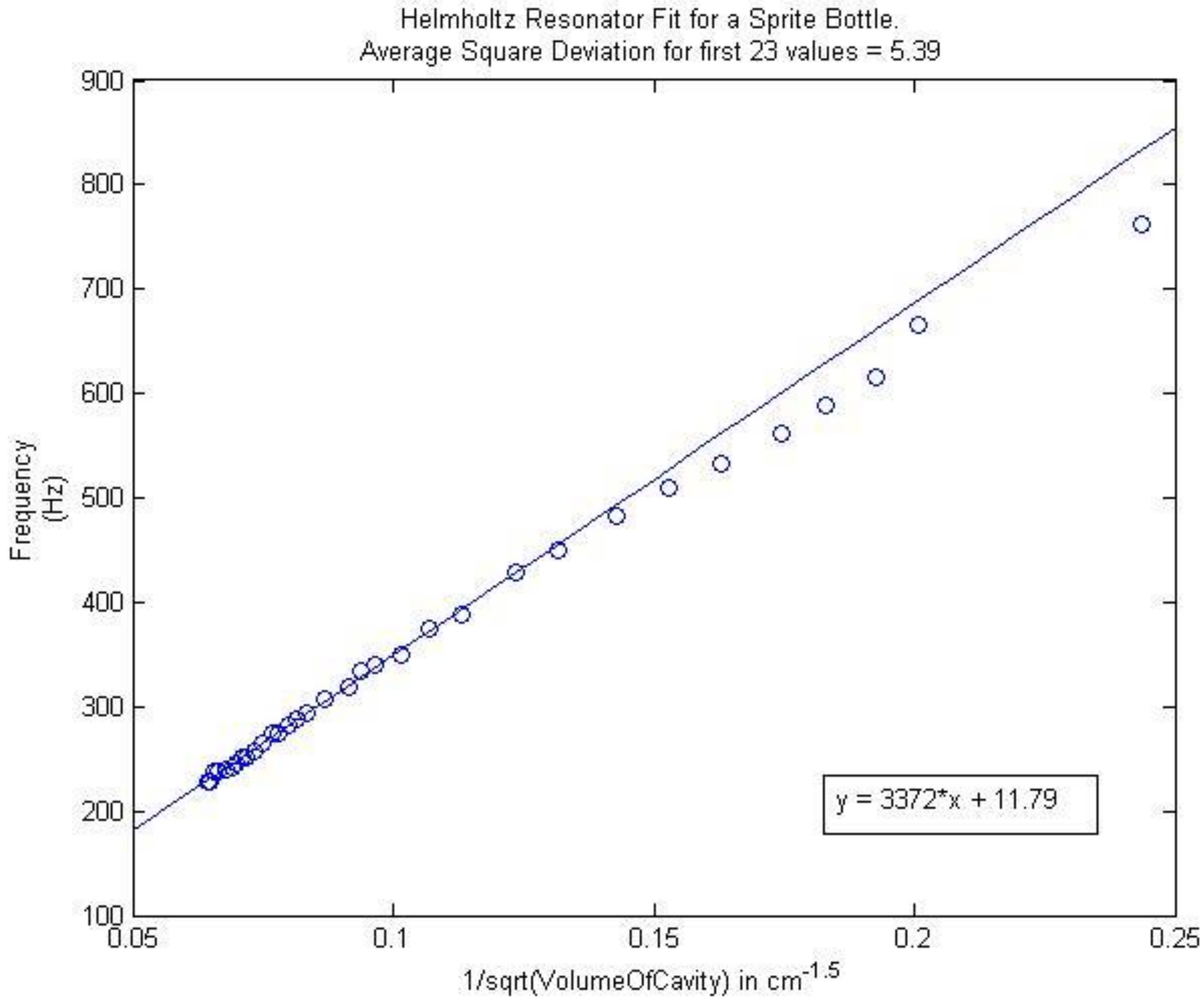
Initial Volume (ml)	Final Volume (ml)	Water Height (cm)	Frequency (Hz)
95.0	89.0	1.00	229
89.0	84.5	0.60	229
84.5	77.0	0.85	237
77.0	72.5	1.05	237
72.5	64.0	1.50	240

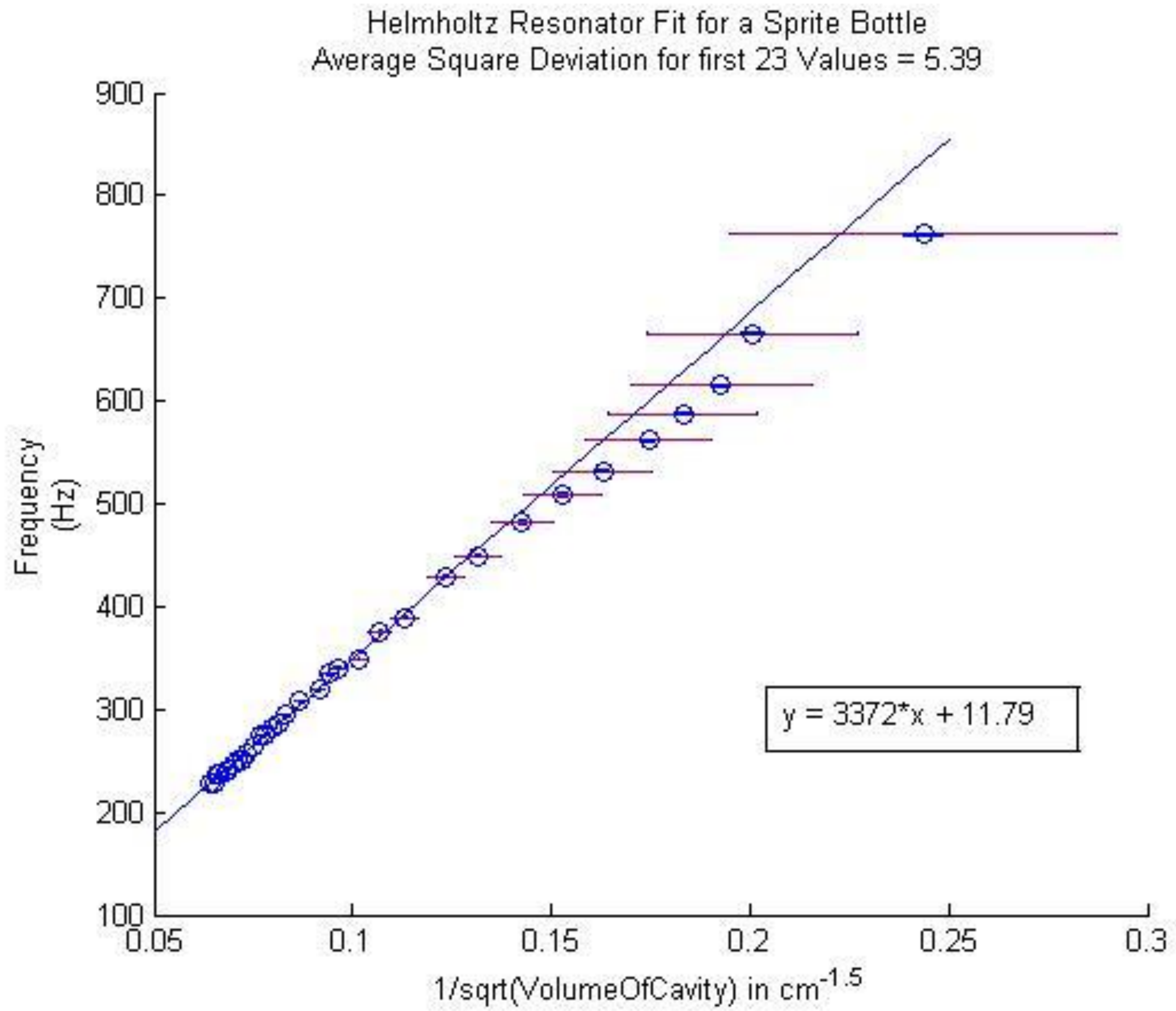
- Plot the frequency against the reciprocal of the square root of cavity volume.
- Compare the graph to that of the predicted values and determine the best value for the height of the boundary above the base of the resonator.

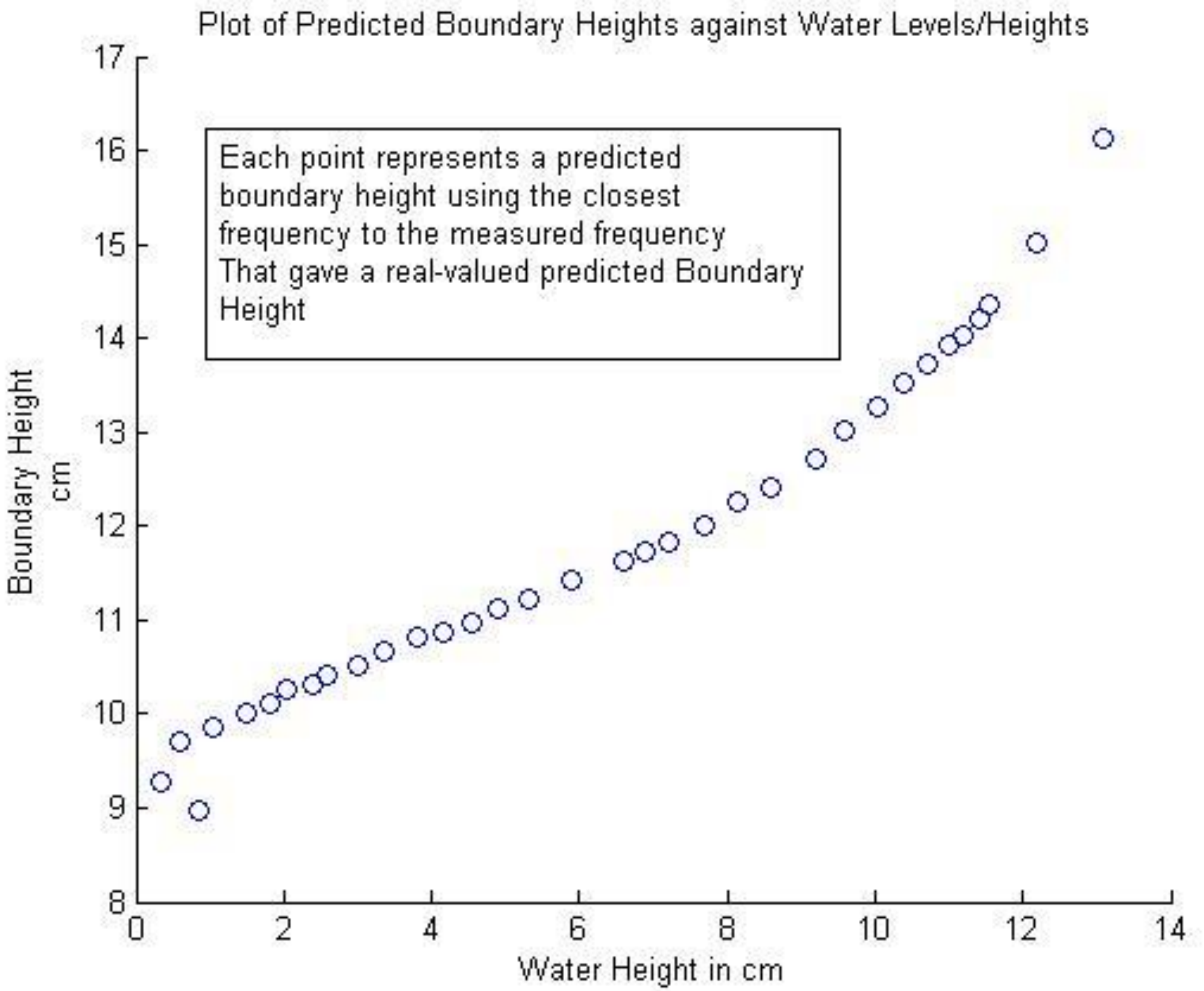
Results

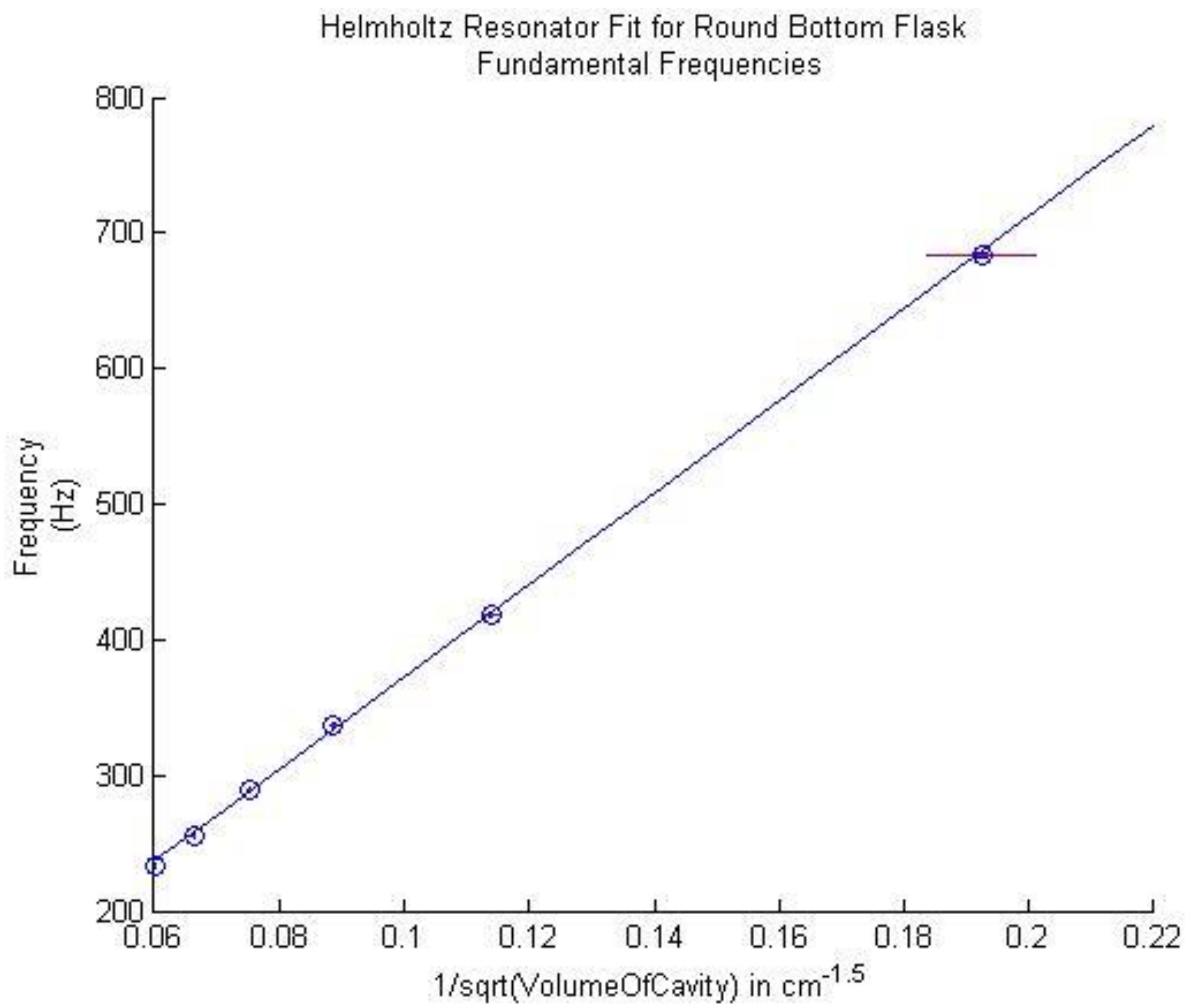


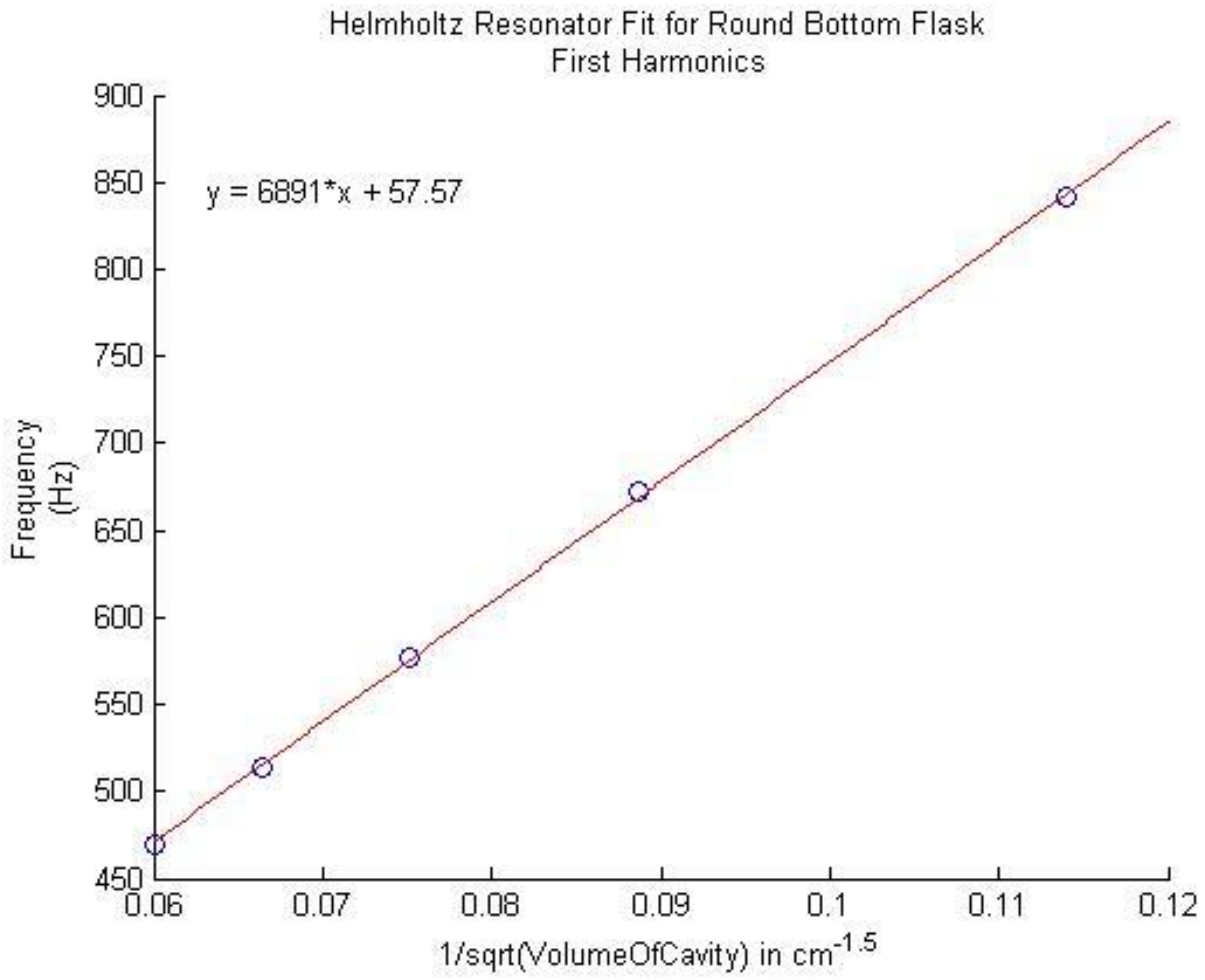
Sample Fourier Transform of a Round bottom flask Resonator


Helmholtz Resonator Fit for a Sprite Bottle.
Average Square Deviation for first 23 values = 5.39
Frequency (Hz)
900
800
700
600
500
400
300
200
100
0.05
0.1
0.15
0.2
0.25
1/sqrt(VolumeOfCavity) in cm^-1.5
y = 3372*x + 11.79


Helmholtz Resonator Fit for a Sprite Bottle
Average Square Deviation for first 23 Values = 5.39
Frequency (Hz)
1/sqrt(VolumeOfCavity) in cm^-1.5
y = 3372*x + 11.79
900
800
700
600
500
400
300
200
100
0.05
0.1
0.15
0.2
0.25
0.3


Plot of Predicted Boundary Heights against Water Levels/Heights
Each point represents a predicted boundary height using the closest frequency to the measured frequency That gave a real-valued predicted Boundary Height
Boundary Height cm
Water Height in cm
17
16
15
14
13
12
11
10
9
8
0
2
4
6
8
10
12
14


Helmholtz Resonator Fit for Round Bottom Flask
Fundamental Frequencies
Frequency (Hz)
800
700
600
500
400
300
200
0.06
0.08
0.1
0.12
0.14
0.16
0.18
0.2
0.22
1/sqrt(VolumeOfCavity) in cm-1.5



Helmholtz Resonator Fit for Round Bottom Flask
First Harmonics
y = 6891*x + 57.57
Frequency
(Hz)
900
850
800
750
700
650
600
550
500
450
0.06
0.07
0.08
0.09
0.1
0.11
0.12
1/sqrt(VolumeOfCavity) in cm-1.5

Citations

- Approximation formulae for the acoustic radiation impedance of a cylindrical pipe - F. Silva, Ph. Guillemain, J. Kergomard, B. Mallaroni, A. N. Norris - http://arxiv.org/pdf/0811.3625.pdf (Nov 21, 2008)