**M2 – Normal modes in an acoustic chamber**

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**Monday group**

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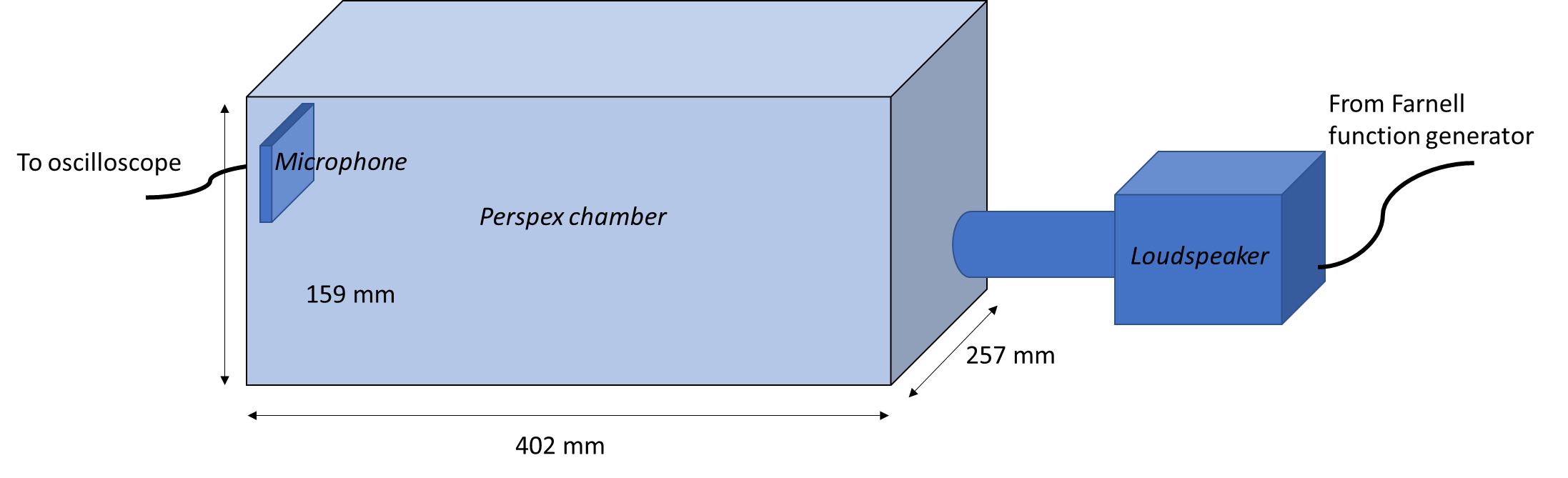
Aims and objectives (A&O)

This experiment intends to explore acoustic phenomena in an acoustic chamber, specifically the occurrence of normal modes across a range of frequencies.

With a chamber of measured dimensions, predictions can be made of the frequencies the sound wave generated will resonate i.e. the modes.

Risk Assessment (RA)

There is not perceived to be any significant risks involved while performing this experiment.

**Apparatus**

*Figure 1: setup of the equipment used in this experiment*

Sound was generated via loudspeaker connected to a Farnell function generator.

Sound waves from this were picked up by the microphone at the other end of the Perspex chamber.

The resulting waves were displayed on a digital oscilloscope screen where frequency and amplitude of the wave could be measured. The Farnell function generator was also connected to the oscilloscope so that the input and output waves could be displayed side by side, and comparisons such as the phase difference could be made.

Experiment section

Initially, the internal dimensions of the Perspex chamber and the length of the tubes were measured using a ruler. A ruler has an error of ±0.5mm at each end of its measurement, resulting in a total error of ±1mm. The Perspex chamber was measured to have dimensions of (257±1) mm by (402±1) mm by (159±1) mm.

Using these dimensions, the predicted frequencies were calculated using the following formula:

Where f is frequency, c is the speed of sound in the chamber, Lx, Ly and Lz are the chamber’s internal dimensions and nx, ny and nz are integers that describes which mode the frequency is being calculated for (i.e. (1,0,0) is the fundamental, which is one half-wavelength along the side Lx.

These calculations were done in Excel with the possible permutations of n generated with [numbergenerator.org](https://numbergenerator.org/permutations-and-combinations). These calculations produced a table of predicted up to 1500 Hz shown below:

|  |  |  |  |
| --- | --- | --- | --- |
| nx | ny | nz | frequency /Hz |
| 0 | 1 | 0 | 426.39 |
| 1 | 0 | 0 | 666.95 |
| 1 | 1 | 0 | 791.60 |
| 0 | 2 | 0 | 852.77 |
| 0 | 0 | 1 | 1078.03 |
| 1 | 2 | 0 | 1082.61 |
| 0 | 1 | 1 | 1159.29 |
| 1 | 0 | 1 | 1267.67 |
| 0 | 3 | 0 | 1279.16 |
| 2 | 0 | 0 | 1333.91 |
| 1 | 1 | 1 | 1337.45 |
| 0 | 2 | 1 | 1374.54 |
| 2 | 1 | 0 | 1400.40 |
| 1 | 3 | 0 | 1442.59 |

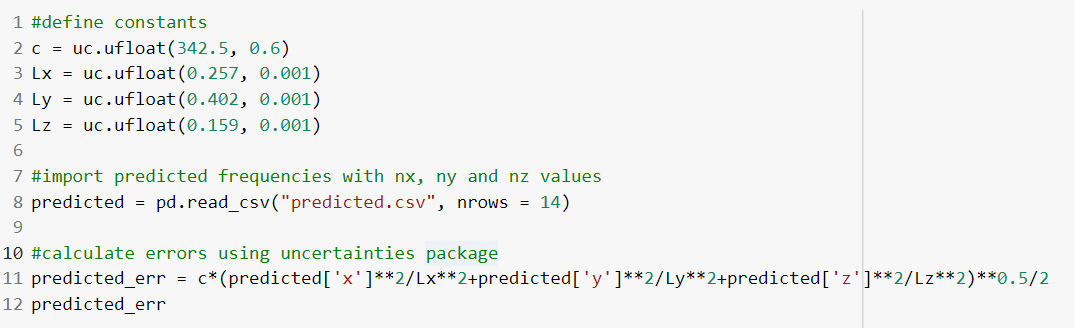
*Table 1: predicted frequency of normal modes in the Perspex chamber*

At the time of measurement, a nearby digital thermometer recorded the room temperature as 19.3°C. Although the resolution of thermometer was 0.1°C, and the thermometer had a digital display, hence removing reading errors, the temperature throughout a room not constant and it would be the temperature inside the box itself that would be the determining factor in speed of sound calculations.

Also, since the experiment was conducted over a two hour period, there would be some temperature fluctuations in the room that would not have been monitored. As such, a sensible best guess for the uncertainty of the measurement was determined to be ±1°C.

A (19 ± 1) °C temperature corresponds to an estimated speed of sound of (342.5 ± 0.6) ms⁻¹.

Using the uncertainties package in python, the corresponding errors for each predicted frequency was calculated. The code used to do this is shown below:



The output of this was:

|  |
| --- |
| **frequency /Hz** |
| 426.0+/-1.3 |
| 666.3+/-2.8 |
| 790.9+/-2.6 |
| 852.0+/-2.6 |
| 1077+/-7 |
| 1081.6+/-3.0 |
| 1158+/-7 |
| 1267+/-6 |
| 1278+/-4 |
| 1333+/-6 |
| 1336+/-6 |
| 1373+/-6 |
| 1399+/-6 |
| 1441+/-4 |

*Table 2: predicted frequencies with uncertainties*

However, it must be remembered that this only accounts for uncertainties in the variable involved in the frequency being measured, not any error that may arise from the act of measuring the frequency itself.

This would be done to the accuracy of the microphone and digital oscilloscope, which are not as easily quantifiable. That said, it was observed that the waves displayed were less stable at lower frequencies.

After the apparatus was setup as shown in figure 1 and all the equipment was turned on, the frequency generated by the Farnell function generator was set to around 400 Hz: just below the predicted frequency of the fundamental, in order to account for errors.

It was observed that the wave displayed on the oscilloscope screen becomes noisier, and less stable, at lower frequencies. This would mean that the uncertainty of measurements increase as frequency is lowered.

The frequency was then slowly increased until the amplitude reach a localised maximum, and the location of this was recorded. This was done up to 1500Hz, and the entire process repeated with the short, medium and long pipes. The results are displayed in table 2.

|  |  |  |
| --- | --- | --- |
| short | medium | long |
| 450 | 450 | 448 |
| 691 | 690 | 689 |
| 811 | 813 | 813 |
| 875 | 869 | 869 |
| 1106 | 1079 | 920 |
| 1183 | 1122 | 1105 |
| 1296 | 1284 | 1289 |
| 1347 | 1344 | 1346 |
| 1398 | 1386 | 1385 |
| 1425 | 1423 | 1422 |
| 1464 | 1459 | 1456 |

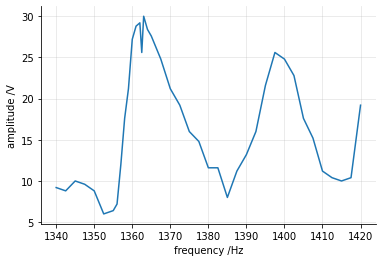
*Table 2: measured frequencies, in Hertz, of the normal modes in the Perspex chamber with a short (69±1) mm, medium (145±1) mm and long (179±1) mm pipe connected*

There seemed to be a systematic error in the measurements, with the short tube’s normal mode frequencies around 30Hz above the predicted frequencies seen in table 2. This is illustrated in the figure 1, where the two are plotted against each other.

*Figure 1: Actual v predicted frequencies of normal modes in Perspex chamber*

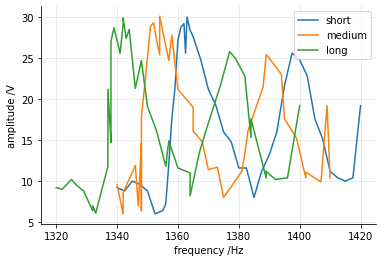
The linear regression equation was generated by excel as having a y-intercept of -31.64, suggesting each measured point is around 31.6 Hz above where it is predicted to be.

The frequency range of 1300Hz to 1400Hz was then explored in more detail, with the amplitude of the wave recorded at small incremental frequencies throughout this range. The Vpp measure on the digital oscilloscope was used to record the amplitude from the microphone.



*Figure 1: amplitude-frequency graph for two modes with the short pipe connected*

This was then repeated for the medium and long pipes, with measurement stopping at the indication of a third peak:



*Figure 2: comparison of amplitudes for the various length pipes*

It was observed that the longer the tube, the lower the frequency of the peaks. This was consistent with results from the first part of the experiment. The medium tube appeared to have a peak 11 Hz lower than the short tube’s peak while the long tube was around 25 Hz lower.

Conclusions

Then experiment intended to explore acoustic phenomena in a Perspex chamber. Results appeared to agree fairly well with predicted frequencies for each normal mode, although all of the measured modes do fall outside of 1 standard error away from the predicted values. That said, the experiment was limited by the equipment available and the environment it was in. Located in a room where a similar experiment was taking place, sound interference due to this was not accounted for, and it must therefore be remembered that the calculated uncertainties were largely underestimated.

If this experiment was repeated, it would be wise to find a quieter environment, as well as perhaps utilise damping materials in order to surround the box and further reduce the impact of external sound waves.