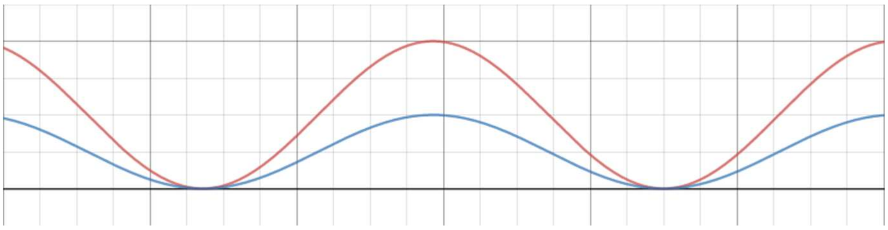
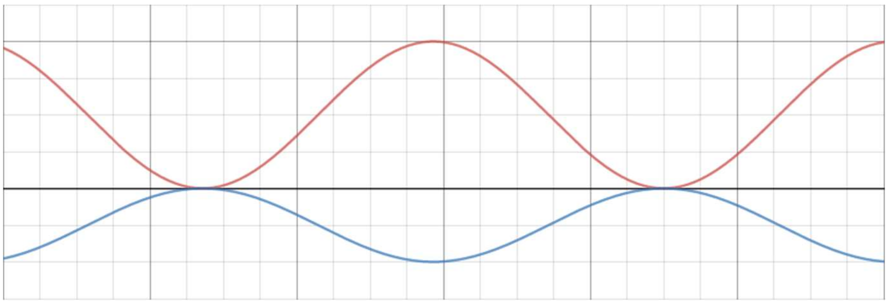
Speed of Sound Investigation

I measured the speed of sound with a simple loudspeaker-microphone-ruler method, to output waves of a given frequency, and calculate their wavelength using an oscilloscope. My setup included a loudspeaker held up by clamp stands and plugged into a wave generator. I lined up a ruler to start exactly at the source of the wave and placed a microphone such that it was able to move along the ruler. I also placed an oscilloscope connected to both the input and output waves, such that I could see both waves on the same screen.

Using this setup, and the ability to change the position each wave was drawn vertically allowed me to find positions where the waves were in and out of phase precisely, by moving the microphone while watching the screen to line the waves up.



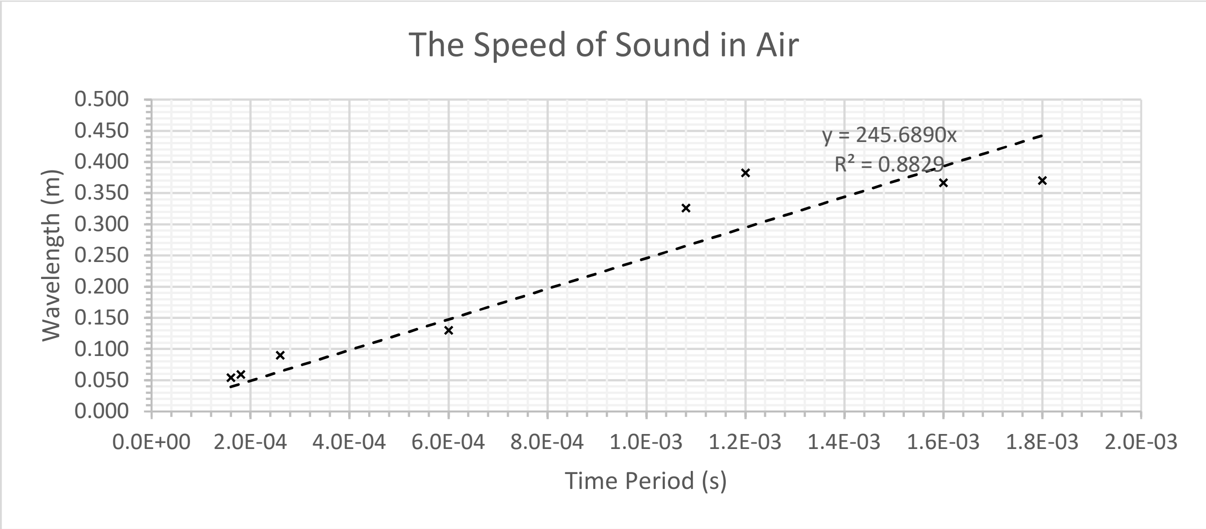
Input (red) and output (blue) in phase. Distance from microphone to speaker is n * λ where n is integer. Time period is distance between points of contact.



Input (red) and output (blue) out of phase by π^r. Distance from microphone to speaker is (n+0.5) * λ where n is integer. Time period is distance between points of contact.

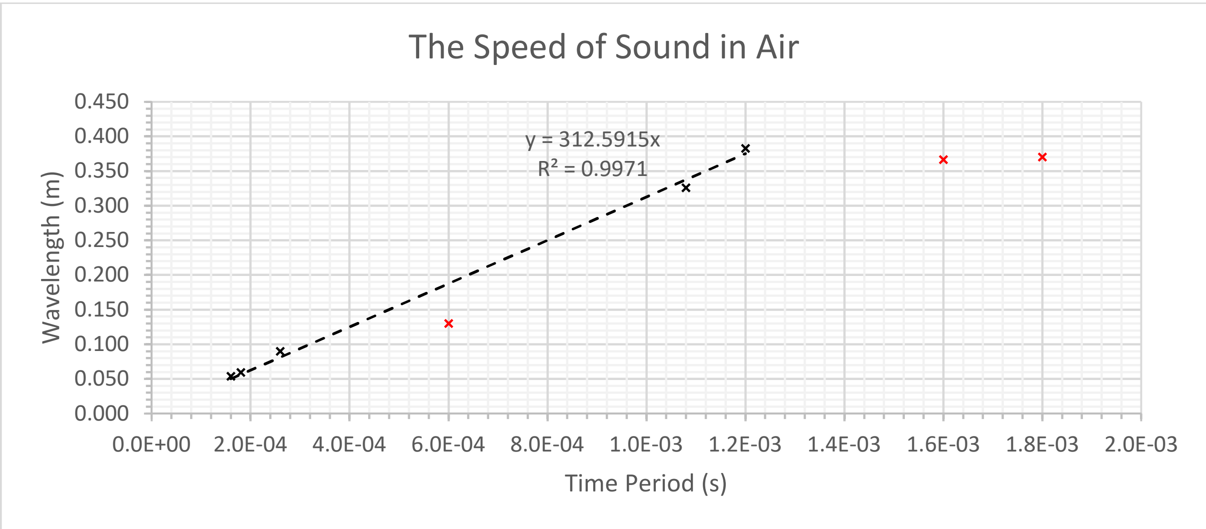
Once I found 2 points where these cases line up, I used the distance the microphone had travelled to find the wavelength of the sound, and the length of the wave on the oscilloscope to find its time period. I did this with 4 separate points where the case lined up, to get 3 distances for half wavelength, then repeated this with many different frequencies of sound. I used these values on a simple distance time graph, plotted a line of best fit with a fixed intercept at 0, and found its gradient for my value of the speed of sound.

Wavelength (m)					Time Period (s)		Speed (ms^{-1})		
L1	L2	L3	Mean	Uncertainty	T1	Uncertainty	S1	Uncertainty	
0.368	0.392	0.388	0.383	±0.14%	1.2E-03	±1.25%	319	±1.39%	±4.42
0.210	0.450	0.450	0.370	±0.24%	1.8E-03	±1.25%	206	±1.49%	±3.06
0.370	0.390	0.340	0.367	±0.15%	1.6E-03	±1.25%	229	±1.40%	±3.20
0.320	0.338	0.320	0.326	±0.16%	1.1E-03	±1.25%	302	±1.41%	±4.24
0.120	0.120	0.150	0.130	±0.42%	6.0E-04	±1.25%	217	±1.67%	±3.61
0.086	0.086	0.098	0.090	±0.58%	2.6E-04	±1.25%	346	±1.83%	±6.34
0.068	0.060	0.050	0.059	±1.00%	1.8E-04	±1.25%	330	±2.25%	±7.42
0.058	0.052	0.052	0.054	±0.96%	1.6E-04	±1.25%	338	±2.21%	±7.46
							286	±2.25%	±6.43



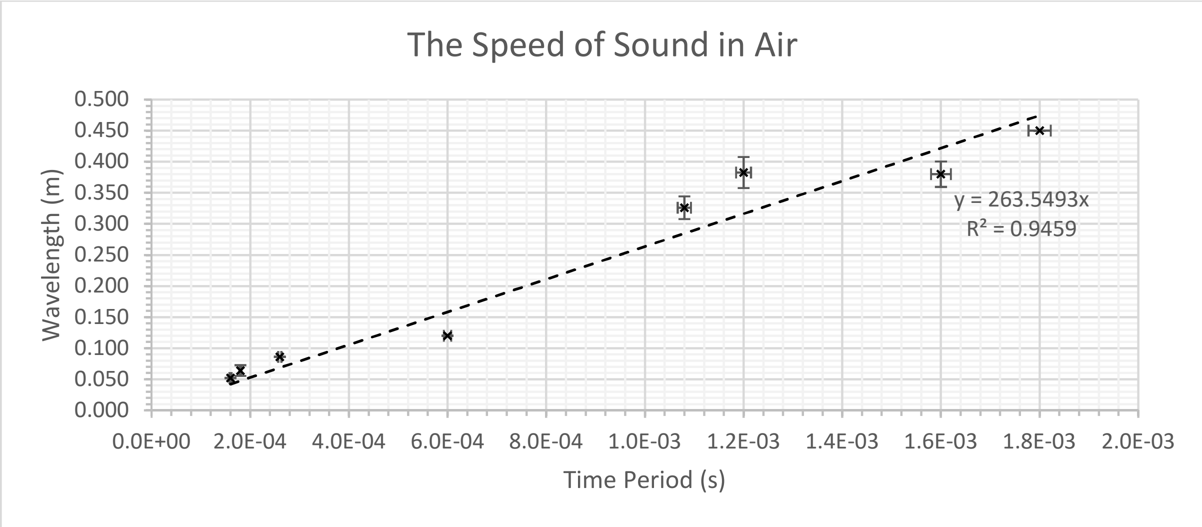
I measured between 500 and 5000Hz, as the further the signal generator got from 1000Hz, the less it was able to generate a clear detectable wave to the oscilloscope and microphone.

The errors in my results strongly suggest a systematic error in my method, as when removing the 3 results far under the line, the line of best fit is much closer to the real speed of sound, $342ms^{-1}$ (at the 18.6°C of the room at the time of recording the results), with a percentage error of 8.68% rather than the 28.23% error beforehand.



Despite this, however, if we use the percentage uncertainty to draw error bars on the graph, as shown in the first graph above, the final data point at 1.8E-03 would have much larger error bars than all the rest of the data. This strongly suggests that there's an anomaly in the averaged 3 readings of that set. If I remove results with uncertainty over a certain level, this results in a graph which is very similar to the one above, meaning I should be able to find the majority of anomaly from within those results.

After removing the results which were furthest from the mean of each set of three, I produced the graph below. This new graph is more precise, and slightly closer to the real value; however, it is still a long way off, and the results are scattered very far from the line of best fit, with uncertainty error bars which do not cover the line. This means that the uncertainties calculated via the "range divided by minimum" method are unsuitable for my set of results.



Another factor I hadn't considered up to this point, is that the time period uncertainties could be the main factor on these results being scattered from the line. I only took a single reading for the time period of each point, and I am only counting the uncertainty as the scale division on the oscilloscope, and not any possible systematic error in the setup of the signal generator. Interestingly, the signal from the generator to the oscilloscope got more random and uncontrolled the further I went from 1000Hz signal, which greatly restricted the set of results I was able to get and could have affected the precision of the results further from the centre of the graph.

The culmination of these factors, along with a generally low data range, resulted in the inaccuracy and lack of precision I can see in the data set, and if I were to repeat this investigation, I would do a few things to ensure that the data resulted in a better trend. Firstly, I would get more readings from as large a range of frequencies as I could, as these would likely produce a much more defined trend in any graphs. I would also take more care in taking the readings of both the wavelength and time period, ensuring that I remove zero error via lining up the front of the speaker and microphone to visible points along the ruler. If possible, using a better microphone, speaker, oscilloscope and signal generator, all with more precision would benefit both the trend in the results, and the efficiency of conducting the experiment, allowing for yet more results.

Lastly, I think the experiment could have benefitted from making an organised table for my results prior to taking them, as organising the results from a very disorganised document likely resulted in a loss of precision, rather than noting down the exact number of squares measured over in the oscilloscope, and either calculating comprehensible values either through a premade program or just after the fact. The disconnect between collecting each result, due to having to keep organising and sorting the data, was likely the source of a lot of the systematic error that caused such a spread of results.

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