Heading

Experiment Title: Measuring the Speed of Sound in Air
Experiment Start Date: 21st October 2021
Experiment Start Time: circa 09.10

Aims

Briefly outline the aims of the experiment.

An experiment was carried out to ascertain the value of the speed of sound in air in a safe manner. To this end, an oscilloscope was used with adjustable time intervals, among other properties: the experiment introduces the basic functions of an oscilloscope.

Background

Briefly outline the theoretical background of the experiment, but do not just repeat what is in the lab manual. Include all important equations that will be used for data analysis. Include any key references.

The speed of sound in air can be determined by using the fact that there is a phase difference between sound waves emitted from a source, and a detector a known distance away. Thus, a microphone may be used to measure the sound and can be connected to an oscilloscope in order to take accurate measurements.

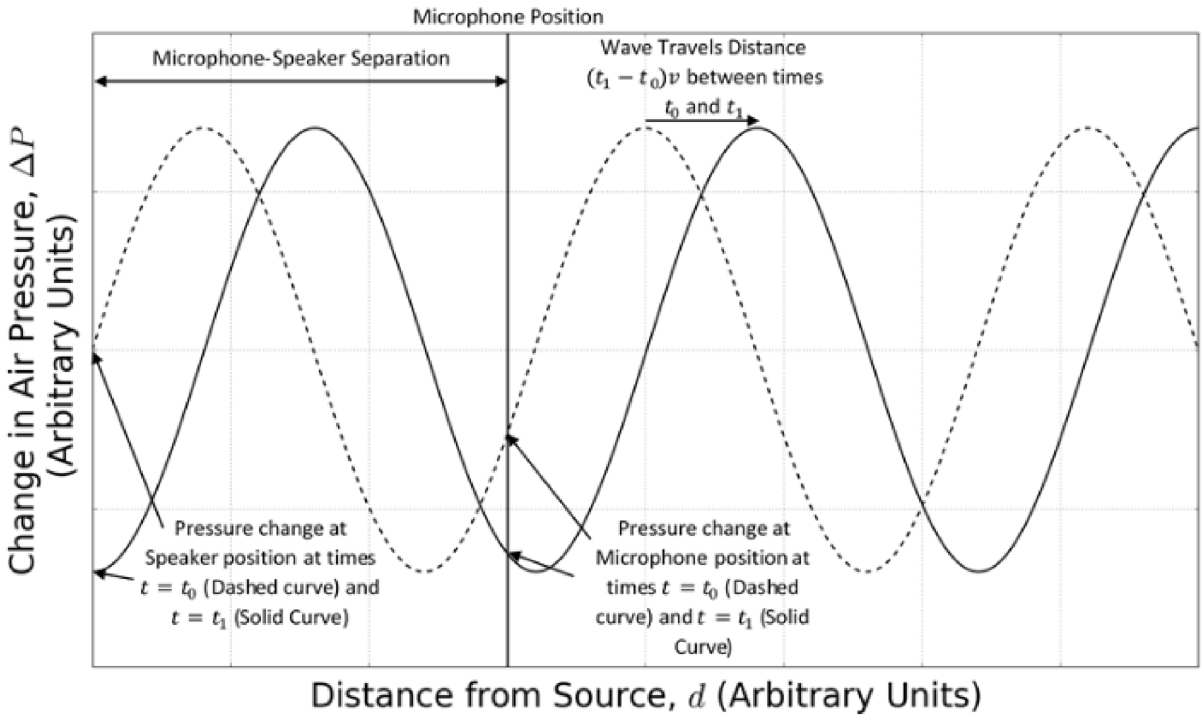


Figure 1: demonstration of the phase shift between a source and a detector, between a time $t = t_0$ and a later time $t = t_1$. The dotted line represents the former, whilst the solid is the latter.

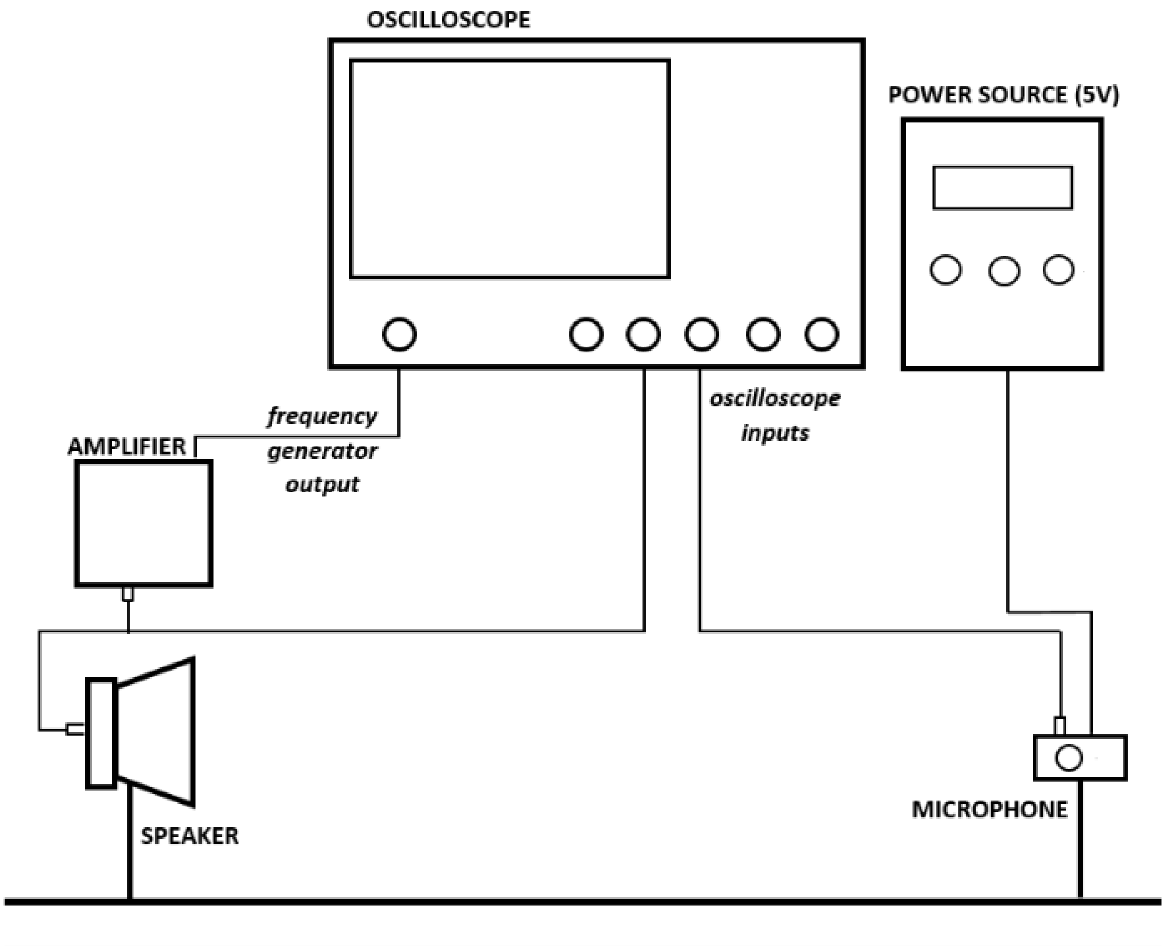
It is known that the phase difference can be defined by this equation: $\Delta\phi = \frac{2\pi}{\lambda}x$ (1), where $\Delta\phi$ is the phase difference, x is source-detector separation and λ represents the wavelength of sound. After recording values of λ and θ, using $c_s = v\lambda$ (2), the speed of sound in air can be determined.

Description of Set Up

Using diagrams and sketches, describe the setup of the experiment. Make it clear which parts are stationary and which parts will be moving.

An oscilloscope is connected to both an amplifier (as an output frequency generator), and to the microphone (as the input to the oscilloscope). A power source of known voltage and current is connected to the circuit and the speaker and microphone lie on a slider, with the speaker in fixed position, and the distance is measured between the speaker and microphone, which is moved along the slider, using a vernier calliper. The oscilloscope is set to a frequency of 20kHz, beyond the human hearing range, and the sound is amplified, ensuring that both horizontal and vertical

scales are re-adjusted to fit the sinusoidal shape clearly on the signal trace (at least a full wavelength should be viewable).



Measurement Strategy

Make rough measurements of the phase shift at various positions, explore the different methods suggested in the lab manual and decide on the method you will use to acquire the data.
Make sure that you document the method and the reasons that you decided on this strategy.

Vernier Caliper Resolution:	20	µm
Metre Rule Resolution:	1	mm
Wavelength (λ):	1.736	cm
Systematic Shift :	31.90	degrees
Frequency:	20000	Hz

The phase difference between the microphone and speaker could be calculated by measuring distance between the two objects using either a ruler, or a vernier caliper. At longer distances beyond the 15cm limit of the vernier caliper, the amplitude of the wave decreased, reducing the precision of measurements. Additionally, the wavelength of the oscillation produced was found to be roughly 1.7cm. Consequently, it made sense for the latter option (i.e. vernier caliper) to be used since it produces results with higher accuracy and the sound preserves its fidelity. Furthermore, the subdivision of 1mm with a wavelength of approximately 17mm means that too small a portion of a wave cycle can be analysed, and the phase of the wave cannot be accurately determined, unlike with vernier calipers that have a resolution of 0.02mm for about 17mm.

Phase Difference Data

We recommend you enter your data into Excel to allow plotting and analysis. You should copy and paste the data into here. Make sure you include information you will need for later analysis (e.g. the frequency that the signal generator is set to).

Data was taken at 5 mm increments, and then 1mm increments for a wave cycle, so that multiple wavelengths of results could be analysed.

Distance / cm	Distance / m	Preliminary Phase Difference / ⁰	Phase Difference from 0 / ⁰	Preliminary Phase Difference / rad	Standard Deviation / ⁰
7.000	0.070	38.3	38.3	0.7	0.8
7.500	0.075	151.8	151.8	2.6	0.1
8.000	0.080	-114.3	245.7	4.3	0.3
8.500	0.085	-9.3	350.7	6.1	0.6
9.000	0.090	94.1	454.1	7.9	0.8
9.500	0.095	-162.4	557.6	9.7	0.3
10.000	0.100	-62.6	657.4	11.5	0.3
10.500	0.105	37.4	757.4	13.2	0.4
11.000	0.110	139.6	859.6	15.0	0.4
11.500	0.115	-113.8	966.2	16.9	0.3
12.000	0.120	-6.1	1073.9	18.7	0.6
12.500	0.125	89.7	1169.7	20.4	0.5
12.600	0.126	109.3	1189.3	20.8	0.2
12.700	0.127	131.4	1211.4	21.1	0.3

12.800	0.128	152.9	1232.9	21.5	0.3
12.850	0.129	162.0	1242.0	21.7	0.8
12.900	0.129	165.3	1245.3	21.7	1.0
12.950	0.130	176.5	1256.5	21.9	0.9
13.000	0.130	-166.9	1273.1	22.2	2.4
13.100	0.131	-148.4	1291.6	22.5	0.2
13.200	0.132	-131.4	1308.6	22.8	0.3
13.300	0.133	-114.9	1325.1	23.1	0.5
13.400	0.134	-91.3	1348.7	23.5	0.4
13.500	0.135	-74.4	1365.6	23.8	2.1
13.600	0.136	-45.6	1394.4	24.3	1.4
13.700	0.137	-32.8	1407.2	24.6	0.2
13.800	0.138	-6.4	1433.6	25.0	0.4
13.900	0.139	11.9	1451.9	25.3	0.8
14.000	0.140	41.7	1481.7	25.9	1.4
14.100	0.141	60.3	1500.3	26.2	0.2
14.200	0.142	71.4	1511.4	26.4	0.2
14.300	0.143	105.8	1545.8	27.0	0.3
14.400	0.144	119.2	1559.2	27.2	0.3
14.500	0.145	150.6	1590.6	27.8	1.7
14.600	0.146	170.3	1610.3	28.1	2.4
14.700	0.147	-167.7	1632.3	28.5	1.4

Phase Difference: Sources of Uncertainty

Note down the various sources of uncertainty and their values in this section.

Vernier Callipher Resolution:	20	μm
Wavelength (λ):	1.736	cm
Systematic Shift :	31.90	degrees
Frequency:	20000	Hz

Data Analysis

Use this section to record the process and outcome of your data analysis

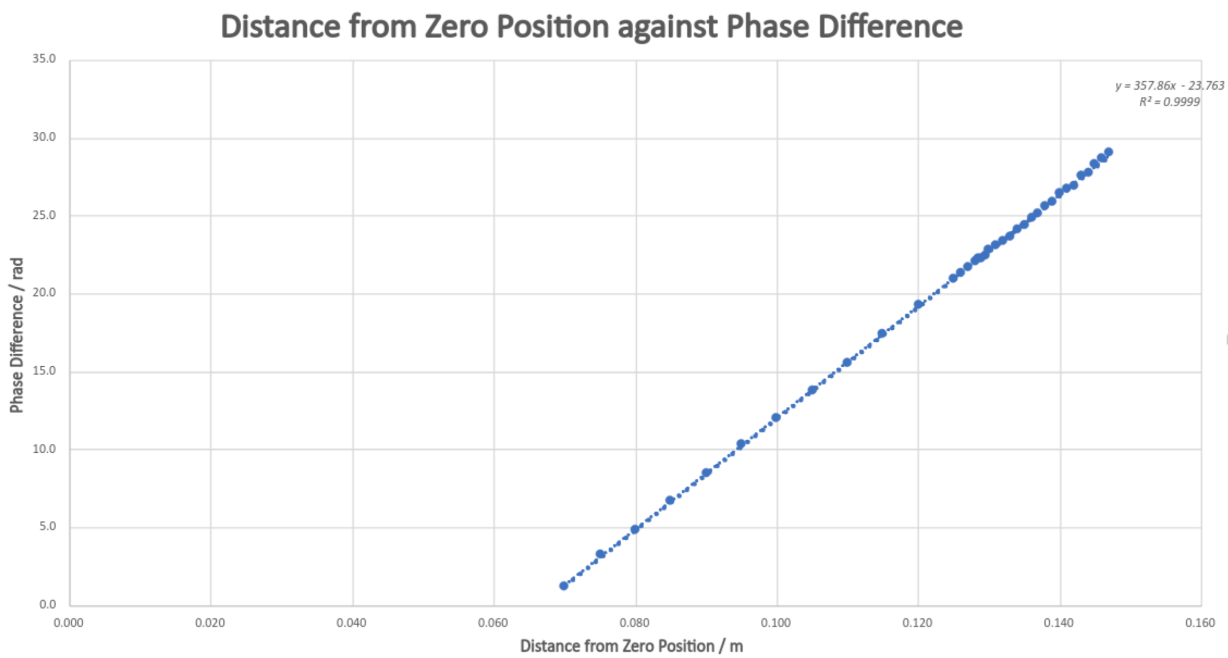
Next, the data was converted from degrees into radians and the standard deviation recalculated:

Distance / m	Actual Phase Difference / rad	Standard Deviation / rad
0.070	1.2	0.014486233
0.075	3.2	0.001919862
0.080	4.8	0.004886922
0.085	6.7	0.009599311
0.090	8.5	0.013439035
0.095	10.3	0.004712389
0.100	12.0	0.004537856
0.105	13.8	0.006806784
0.110	15.6	0.007504916
0.115	17.4	0.005759587
0.120	19.3	0.009599311
0.125	21.0	0.008726646
0.126	21.3	0.00296706
0.127	21.7	0.004712389
0.128	22.1	0.004537856
0.129	22.2	0.014660766
0.129	22.3	0.01727876
0.130	22.5	0.015882496
0.130	22.8	0.041887902
0.131	23.1	0.00296706
0.132	23.4	0.005585054
0.133	23.7	0.009075712
0.134	24.1	0.007330383
0.135	24.4	0.036302848

0.136	24.9	0.024085544
0.137	25.1	0.003839724
0.138	25.6	0.007330383
0.139	25.9	0.013439035
0.140	26.4	0.024085544
0.141	26.7	0.004014257
0.142	26.9	0.003665191
0.143	27.5	0.004886922
0.144	27.8	0.005061455
0.145	28.3	0.028972466
0.146	28.7	0.042586034
0.147	29.0	0.023911011

From the graph, it can be found out that the trend line follows $y = 357.86x - 23.763$, $R^2 = 0.9999$. Following (1) and (2), $c_s = \frac{2\pi}{gradient} \cdot f \qquad (3)$, therefore, the calculated value of speed of sound is:

$$c_s = \frac{2\pi}{357.86} \cdot 20000 = 351\, m \cdot s^{-1}\, (3.s.f)$$



Summary

Briefly summarise the main outcomes of the experiment

To summarise,