Core practical 6: Determine the speed of sound in air using a 2-beam oscilloscope, signal generator, speaker and microphone

Objective

- To use appropriate instrumentation to measure a sound signal

Safety

- The electromotive forces are small and electric currents negligible.
- The sound should not need to be so loud that any discomfort is felt.
- Follow the usual electrical precautions for mains apparatus including a visual inspection of the supply lead.

Specification links

- Practical techniques 1, 3, 8, 9
- CPAC 2a, 2d, 4a

Notes on procedure

- This experiment is reasonably straightforward for students familiar with manipulating the controls of an oscilloscope. Time will need to be devoted to training them to set up a trace from which they can take measurements.
- Since the set up depends on the local circumstances this is something of an investigation and the students should be encouraged to try things out for themselves using the instructions as a framework.

Procedure

1. The oscilloscope will display on two traces the signal fed to the loudspeaker and the signal received by the microphone. As the distance between the microphone and the speaker is increased, the phase of the signals varies and the traces on the screen move past each other.
2. Place the microphone next to the oscilloscope and place the speaker about 50 cm away, facing the microphone. Turn on the signal generator and set it to about 4 kHz. Adjust the oscilloscope to show the microphone signal with about three cycles on the screen.
3. Connect the signal generator output to the second oscilloscope input (as well as the speaker) and adjust the controls to display three cycles of this signal.
4. Adjust the spacing on the screen and the distance between the speaker and microphone so that the bottom of one trace is just level with the top of the other.
5. Adjust the separation so that a trough on the top trace exactly coincides with a peak on the lower trace. Place the metre ruler alongside the microphone and speaker and record the distance between the microphone and speaker.
6. Move the speaker away from the microphone and observe one trace sliding over the other. Move the speaker so that the trace has moved exactly one cycle. The troughs and peaks should just touch again. Record the new distance between the microphone and speaker. The difference between the two distances is one wavelength.
7. Continue to move the speaker away from the microphone and record each successive distance where the peaks of one trace coincide with the troughs of the other.
8. Calculate a mean value for the wavelength of the sound and estimate the uncertainty in this measurement.
9. Use one of the traces to determine the frequency of the sound. You will achieve a greater resolution this way than using the scale on the signal generator. Estimate the uncertainty in this measurement. You should be able to measure the frequency to three significant figures and the wavelength to at least two.
10. Using the scale on the signal generator, halve the frequency and repeat the measurements for frequency and wavelength. You might need to increase the separation beyond 1 m.
11. You might try this experiment at much higher and lower frequencies to observe the effect.

Answers to questions

1. The trace on the screen can be quite thick and so there is some uncertainty about exactly where to place the speaker each time. Similarly, the resolution of the screen measurement for the frequency is about 2 mm.
2. The percentage difference might well be very small if the measurements are accurate. The percentage uncertainties are likely to be about 2% each. So this looks like an accurate result and is likely to be close to the true value on the day.
3. Since the *x*-axis displays time, we can tell that the sound is taking one extra period to travel from the speaker to the microphone. The distance travelled in one period is the wavelength.
4. We need a wavelength that can be measured to a good resolution using a metre ruler.

Sample data

- **At 4 kHz nominal**

  Positions (in cm) of speaker such that traces coincide:

  121.5, 113.0, 104.5, 96.0, 87.5, 78.7, 69.5, 61.0

  mean difference = 8.6 cm ± 0.3 cm

  measurements of the trace give a frequency of 4050 Hz ± 100 Hz

  speed = 348 ms^{-1}

- **At 2 kHz nominal**

  Positions (in cm) for speaker such that traces coincide:

  104.0, 90.0, 73.0, 55.5, 40.0, 22.5

  mean difference = 16.3 cm ± 1.8 cm

  measurements of the trace give a frequency of 2110 Hz ± 50 Hz

  speed = 344 ms^{-1}

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All the maths you need

- $v = f \times \lambda$ and $f = \frac{1}{T}$ where T is the period of one complete oscillation. You can measure this from the oscilloscope screen.
- Recognise and make use of appropriate units in calculations.
- Use ratios, fractions and percentages.
- Use an appropriate number of significant figures.
- Find arithmetic means.
- Identify uncertainties in measurements and use simple techniques to determine uncertainty when data are combined by addition, subtraction, multiplication, division and raising to powers.
- Substitute numerical values into algebraic equations using appropriate units for physical quantities.

Equipment

- signal generator with loudspeaker
- oscilloscope with 2-beam facility and microphone connected to one input
- 2 metre rulers
- leads

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2. Place the microphone next to the oscilloscope and place the speaker about 50 cm away, facing the microphone. Turn on the signal generator and set it to about 4 kHz. Adjust the oscilloscope to show the microphone signal with about three cycles on the screen.
3. Connect the signal generator output to the second oscilloscope input (as well as the speaker) and adjust the controls to display three cycles of this signal.
4. Adjust the spacing on the screen and the distance between the speaker and microphone so that the bottom of one trace is just level with the top of the other.
5. Adjust the separation so that a trough on the top trace exactly coincides with a peak on the lower trace. Place the metre ruler alongside the microphone and speaker and record the distance between the microphone and speaker.
6. Move the speaker away from the microphone and observe one trace sliding over the other. Move the speaker so that the trace has moved exactly one cycle. The troughs and peaks should just touch again. Record the new distance between the microphone and speaker. The difference between the two distances is one wavelength.
7. Continue to move the speaker away from the microphone and record each successive distance where the peaks of one trace coincide with the troughs of the other.

8. Calculate a mean value for the wavelength of the sound and estimate the uncertainty in this measurement.
9. Use one of the traces to determine the frequency of the sound. You will achieve a greater resolution this way than using the scale on the signal generator. Estimate the uncertainty in this measurement. You should be able to measure the frequency to three significant figures and the wavelength to at least two.
10. Using the scale on the signal generator, halve the frequency and repeat the measurements for frequency and wavelength. You might need to increase the separation beyond 1 m.
11. You might try this experiment at much higher and lower frequencies to observe the effect.

Analysis of results

1. Multiply your values for wavelength and frequency to obtain a value for the speed of sound for each of the frequencies used. Hence, find a mean and percentage difference.
2. Use the uncertainties from your measurements to calculate a percentage uncertainty in your individual values for the speed of sound.

Questions

1. Comment on the sources of uncertainty in this investigation.
2. Compare your percentage difference and your percentage uncertainties and comment on your result.
3. When the traces slide one cycle past each other, the speaker has moved one wavelength. Explain this.
4. Explain why 4 kHz is a suitable frequency for this experiment.

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Equipment per student/group	**Notes on equipment**
signal generator with loudspeaker	
oscilloscope with 2-beam facility and microphone connected to one input	A picoscope would be fine.
2 metre rulers	Measuring tapes would be fine.
leads	Leads will need to be long enough to enable the loudspeaker to be moved up to 1.5 m from the oscilloscope. The signal generator can be between them.

Notes