Advanced Higher Physics: Assignment Support

Astronomy & Physics Education Group

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Measuring speed of sound using Kundt's tube

Introduction: Interfering waves

A longitudinal sound wave travelling in a tube of air can be described mathematically as follows:

$$y_1(x,t) = A\cos\left[2\pi\left(ft - \frac{x}{\lambda}\right)\right]$$

[1]

where A is the amplitude of the wave, f the frequency and λ the wavelength. x and t are the position in the tube we want to determine y_1 and the time we make the measurement, respectively. If the wave reflects off the end of the tube, then the reflected wave is represented by

$$y_2(x,t) = B\cos\left[2\pi\left(ft + \frac{x}{\lambda}\right)\right]$$

[2]

The change of the – for + in the equation is because of the change of direction; B is the amplitude of the reflected wave. When these two waves meet, they interfere and create a standing wave. If we assume that no energy is lost on reflection, then $B = A$, and the combined wave can be expressed as

$$y_{\text{net}} = 2A\sin(2\pi ft)\sin\left(\frac{2\pi x}{\lambda}\right)$$

[3]

Whilst waves y_1 and y_2 caused disturbances in the air that moved along the tube – hence the term "travelling waves" – a standing wave creates disturbances with no *net* movement. Disturbances oscillate back and forth about equilibrium positions.

With a standing wave you get points known as nodes and antinodes:

- Nodes are points where, for all values of t, the net displacement is zero.
- Antinodes are point where, for all values of t, the net displacement is maximum - $2A$ here.

The locations of the nodes can be determined by considering equation [3]:

$$y_{\text{net}} = 2A\sin(2\pi f t)\underbrace{\sin\left(\frac{2\pi x}{\lambda}\right)}_{\text{(i)}}$$

(i) here determines the locations of the nodes. If we set this equal to zero, we see that …

$$\sin\left(\frac{2\pi x}{\lambda}\right) = 0 \Rightarrow \frac{2\pi x}{\lambda} = n\pi \Rightarrow x = \frac{n\lambda}{2}$$

where n is an integer. The distance between adjacent nodes, e.g. between the nodes at $n = 1$ and $n = 2$ is therefore

$$(\Delta x)_{\text{node}} = \frac{\lambda}{2}$$

[4]

The spacing between adjacent antinodes is also half the wavelength. So, if the distance between nodes (or antinodes) is measured it is possible to determine the wavelength of the sound wave and hence the speed, v, assuming that the frequency, f, is also known since

$$v = f\lambda$$

[5]

The Kundt's tube

The Kundt's tube (named after the man who invented it in1866, August Kundt) experiment allows for the creation of standing sound waves. At one end of the tube there is a loudspeaker; at the other end is a microphone on a sliding Perspex cylinder. This cylinder/microphone combination can be moved along the length of the tube by pulling on the cable connecting it to the oscilloscope (labelled CRO) or by a nylon thread attached to the front of the cylinder. This set up is shown in Figure 1.

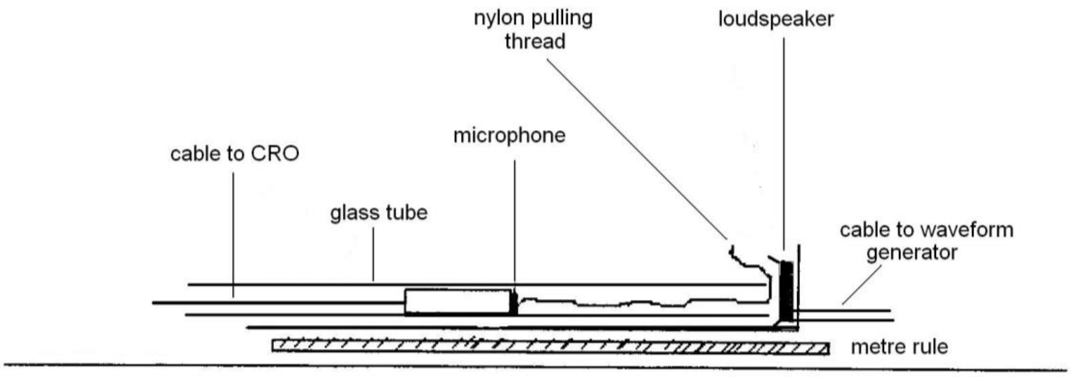

Figure 1: The Kundt's tube

Monitoring the output from the microphone on the CRO allows for the locations of minima (nodes) and maxima (antinodes) to be identified.

Notes on equipment

Equipment list

The equipment provided for this Experiment are:

- The Kundt's tube
- Loudspeaker and signal generator
- Microphone and oscilloscope
- Metre rule
- Dry wipe marker

Equipment guidance

CRO:

The display on the oscilloscope should be adjusted to make sure that the signal is as clear as possible. By monitoring the amplitude – the height – of the signal on the screen it is possible to determine when the microphone is at a point of maximum, or minimum, amplitude.

Signal generator:

This can generate a wide range of signals – it is recommended to choose a frequency that will create a standing wave pattern with anti-nodes separated by around $10\ \mathrm{cm}$. By using the accepted value for the speed of sound in air of $\sim 340\ \mathrm{ms}^{-1}$ it is possible to determine a suitable value for f.

Kundt's tube:

It is best to use as much of the length of the tube as possible, so starting by positioning the microphone at an anti-node around three-quarters of the way along the tube is recommended. It should then be possible to determine the position of several anti-nodes before reaching the other end of the tube.

Locations of anti-nodes can be marked on the tube using dry wipe markers.

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