P1-A1 Measurement of the speed of sound in the air by the phase shift method (oscilloscope)

Theoretical background

Acoustic wave, wave equation, quantities characterizing an acoustic wave. Wave phase, phase shift. The speed of sound in different media. Velocity of sound in air, dependence on pressure and temperature. The principle of operation of the oscilloscope. Lissajous curves.

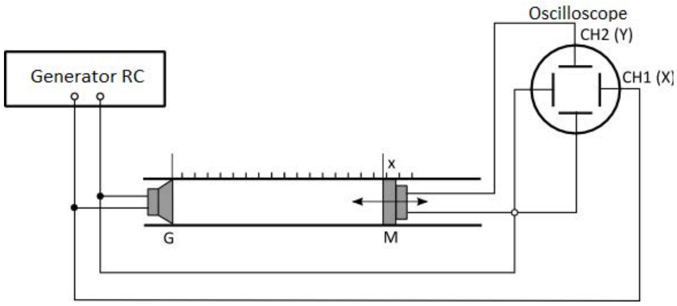
1. Introduction

A detailed description of the acoustic wave and its characteristics can be found in this chapter of the OpenStaxx manual.

2 Measuring system

The diagram of the measurement system is shown in

the drawing.

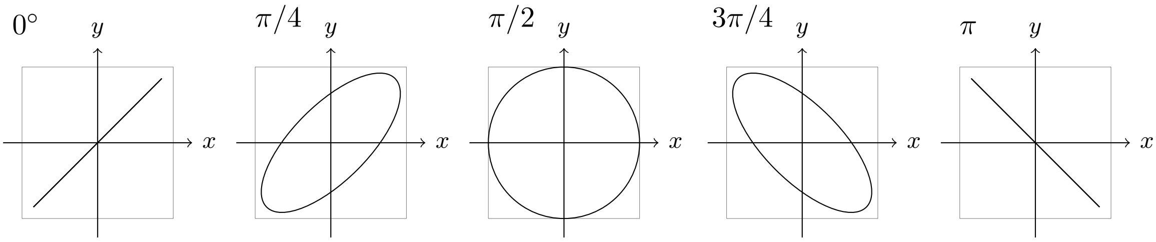


The source of the acoustic wave in a Kundt tube is a loudspeaker connected to a waveform generator. It generates a sound of constant intensity and frequency. The signal receiver is a microphone mounted on a movable piston, whose position in relation to the loudspeaker is read from the ruler. It is a condenser microphone, one of the covers of which is the microphone diaphragm, which moves under the influence of the acoustic wave. The movement of the diaphragm causes changes in the voltage between the plates of the capacitor, recorded by the oscilloscope. By changing the position of the piston, the wave propagation conditions change.

3 Measurements

1. Read the temperature in the laboratory and its uncertainty from the thermometer in the laboratory.
2. Turn on the AC signal generator and the oscilloscope.
3. Set the frequency of the alternating waveform fed to the loudspeaker on the generator: 1500 Hz.
4. Moving the microphone, observe the behavior of the ellipse on the oscilloscope screen.
5. Note down the microphone positions at which the ellipse turns into an oblique line, inclined at an angle of 45 $^\circ$ or 135 $^\circ$ to the horizontal.

6. Repeat the measurements for other frequencies.



4 Data analysis

1. Calculate the distances between the position of the microphone where the phase difference of the loudspeaker and microphone signal differs by π

$$\Delta x = x_{i+1} - x_i.$$

2. Calculate the average value of Δx_{ave}, and its total uncertainty, taking into account the uncertainty of the averaging $u_a(x_{\text{ave}})$ and the accuracy of the device used to measure the distance $u_b(x)$.
3. Calculate the speed of sound according to the formula

$$c = 2f\Delta x_{\text{ave}},$$

   where f – frequency of alternating voltage applied to the loudspeaker.
4. Using the uncertainty transfer law, calculate the uncertainty of the determined velocity.
5. Similar calculations were carried out for the remaining frequencies of the acoustic wave.
6. Calculate the weighted average of the obtained sound velocities in air and the uncertainty of the weighted average.
7. Test the consistency of the obtained c value with the theoretical value of the speed of sound for dry air at the temperature in the laboratory. Comment on the test result.
8. Calculate the exponent of the adiabat equation

$$\kappa = \frac{\mu c^2}{RT},$$

   where $R = 8.31$ J/(mol·K) - universal gas constant, $\mu = 28.87$ g/mol - molar mass of air, T - air temperature, expressed in K.
9. Using the uncertainty transfer law, calculate the uncertainty of the obtained adiabat coefficient and write it in the appropriate format.
10. Carry out a consistency test of the obtained κ value with the table value. Comment on the test result.