Score

Physical Experiment Ⅱ

Physics Lab Report 13

Experiment Title：	Measuring the Ultrasonic Speed
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Lab Date：	2018.11.22

Score

Abstract (About 100 words, 3 points)

The purpose of this experiment is to make us understand the production of ultrasonic sound by piezoelectric transducers and compute the ultrasonic sound speed after measuring the ultrasonic sound wavelength with standing wave and phase comparison methods. The former method computes the ultrasonic sound wavelength by using the distance between adjacent nodes or antinodes, while the latter method uses Lissawwjous patterns to determine the wavelength and then measure the phase difference of the two wave forms. In this experiment, we obtained the final result of ultrasonic speed: $(350 \pm 0.168)m/s$, with the relative error (2.33%).

Score

Introduction (3 points)

Ultrasonic sound waves are longitudinal with frequencies greater than 20khz which exceeds the limit of the human hearing range. And they are used to measure distances, detect objects and clean. After performing this experiment and analyzing the data, we are supposed to understand the production of ultrasonic sound by piezoelectric transducers and measure the speed of the ultrasonic sound waves by two methods of standing waves and phase changes.

Score

Experimental Procedure (State main steps in order of performance, 3 points)

①Turn on the oscilloscope and the function generator;

②Choose sinusoidal wave with frequency 35.000kHz from the function generator;

③Adjust the distance between the transmitter and the receiver to about 5mm;

④In the standing wave method, move the receiver slowly to increase the distance between the transmitter and the receiver, and record the position when the amplitude of the sine wave reaches the maximum;

⑤In the phase comparison method, turn the TIME/DIV knob of the oscilloscope fully anticlockwise to observe a Lissajous pattern and move the receiver until the line with positive slope to record the position of the receiver.

⑥Record the room temperature.

Score

Results (Data tables and figures, 2 points)

1. Data Tables

DATA TABLE 6-1 (*purpose*: to measure the ultrasonic sound wavelength with standing wave method)

Resonance frequency f= 35.00 kHz; Room temperature T= 18 ℃ ;

Trial	1	2	3	4	5	6	7	8	9	10
l_i（mm）	5.845	10.865	15.860	20.845	25.860	30.855	35.860	40.865	45.845	50.850

DATA TABLE 6-2 (*purpose*: to measure the ultrasonic sound wavelength with phase comparison method)

Trial	1	2	3	4	5	6	7	8	9	10
L_i（mm）	3.305	10.350	18.530	27.010	32.315	39.165	46.350	55.160	67.780	74.585

Score

Discussion (More than 150 words, 5 points)

Based on the knowledge of piezoelectric transducers and the ultrasonic sound waves, we obtained the ultrasonic speed by standing wave and phase comparison methods. The former method computes the ultrasonic sound wavelength by using the distance between adjacent nodes or antinodes, while the latter method uses Lissajous patterns to determine the wavelength and then measure the phase difference of the two wave forms. In this experiment, the relative error of result by standing wave method and phase comparison method are 2.33% and 24.41%, respectively. By analyzing the experiment method and details with experimental knowledge, I think the errors in the standing wave method is probably caused by reading errors, the misreading of the max amplitude and the corresponding frequency value. While the errors in the phase difference method is likely caused by distinguishing the Lissajous patterns inaccurately.

Score

Conclusions (About 50 words, 2 points)

In this experiment, I have understood more about how to measure the ultrasonic sound wavelength by two methods (standing wave method and phase comparison method). After recording the data and doing uncertainty calculations, we obtained the final result of ultrasonic speed: $(350 \pm 0.168)m/s$, with just 2.33% relative error.

Score

References (1 points)

Haofu, Esmond Agurgo Balfour, Introductory Physics Experiments for Undergraduates, Science Press, Beijing, 2017

Score

Answers to Questions (6 points)

(1) Just adjust the frequency of the sine wave from the function generator. And we can receive the output voltage and get the pattern from the oscilloscope. When the amplitude of the sine wave shown on the screen reaching its maximum, which means the transmitter is in resonance at that time.

(2) I think the phase comparison method is more accurate comparing to the standing wave method.

Because it is more accurate and easier to observe the Lissajous patterns shown on the screen.

While for the standing wave method, we have to make sure if the superposition reaches its maximum value with difficulties and errors, since the pattern changes a lot when we adjust the apparatus a little.

Appendix

Score

(Calculations, 15 points)

6.1 Compute the ultrasonic sound speed measured by standing wave method

(1) Compute the accepted value of the ultrasonic sound velocity in air by the following formula.

$$V_0 = 331.30\times\sqrt{\frac{T}{T_0}}\ (T_0\text{=273.15 K})$$

Thus, $V_0 = 331.30\times\sqrt{\frac{291.15}{273.15}} = 342.04\ m/s$

(2) Compute the wavelength measured by standing wave method.

$\overline{\lambda_s} = \frac{2}{25}[|l_{10} - l_5| + |l_9 - l_4| + |l_8 - l_3| + \cdots + |l_6 - l_1|] = \frac{2}{25}[|50.850 - 25.860| + |45.845 - 20.845| + |40.865 - 15.860| + |35.860 - 10.865| + |30.855 - 5.845|] = 10mm$

(3) Compute the ultrasonic sound velocity.

$\overline{V_s} = \overline{\lambda_s}\times f = 10\times10^{-3}\times35.00\times10^3 = 350m/s$

(4) Compute the relative error.

$E_s = \frac{\overline{V_s}-V_0}{V_0}\times100\% = \frac{350-342.04}{342.04}\times100\% = 2.33\%$

6.2 Compute the ultrasonic sound speed measured by phase comparison method

(1) Compute the wavelength measured by phase comparison method.

$$\overline{\lambda_p} = \frac{1}{25}[|L_{10} - L_5| + |L_9 - L_4| + |L_8 - L_3| + \cdots + |L_6 - L_1|]$$

$\overline{\lambda_s} = \frac{1}{25}[|l_{10} - l_5| + |l_9 - l_4| + |l_8 - l_3| + \cdots + |l_6 - l_1|] = \frac{1}{25}[|74.585 - 32.315| + |67.780 - 27.010| + |55.160 - 18.530| + |46.350 - 10.350| + |32.315 - 3.305|] = 7.39mm$

(2) Compute the ultrasonic sound velocity.

$$\overline{V_p} = \overline{\lambda_p} \times f = 7.39 \times 10^{-3} \times 35.00 \times 10^{3} = 258.55 m/s$$

(3) Compute the relative error.

$$E_p = \frac{\overline{V_p} - V_0}{V_0} \times 100\% = \frac{258.55 - 342.04}{342.04} \times 100\% = 24.41\%$$

6.3 Compute the uncertainty in the ultrasonic sound speed measured by standing wave method

(1) Compute the following difference in positions.

$L_1 = |l_6 - l_1| = |30.855 - 5.845| = 25.010$, $L_2 = |l_7 - l_2| = |35.860 - 10.865| = 24.995$,
$L_3 = |l_8 - l_3| = |40.865 - 15.860| = 25.005$, $L_4 = |l_9 - l_4| = |45.845 - 20.845| = 25.000$,
$L_5 = |l_{10} - l_5| = |50.850 - 25.860| = 24.990$,

$$\bar{L} = \frac{1}{5}(L_1 + L_2 + L_3 + L_4 + L_5) = 25mm$$

(Note: In the following calculations, L_1, L_2, L_3, L_4, L_5 are treated as direct measurement results.)

(2) Compute the type A uncertainty in $\bar{L}$.

$$\mu_{A_{\bar{L}}} = \sqrt{\frac{\sum_{i=1}^{5}(L_i - \bar{L})^2}{5 \times (5-1)}} = \sqrt{\frac{(0.010)^2 + (0.005)^2 + (0.005)^2 + (0.000)^2 + (0.010)^2}{5 \times (5-1)}} = 0.0035 mm$$

(3) Compute the type B uncertainty in $\bar{L}$.

$$\mu_{B_{\bar{L}}} = \frac{\Delta_{Instr.}}{\sqrt{3}} = \frac{0.02}{\sqrt{3}} = 0.0115 mm$$

(Note: L is measured by a vernier caliper and there is no reading error.)

(4) Compute the combined uncertainty in L.

$$\sigma_L = \sqrt{\mu_{A_{\bar{L}}}{}^2 + \mu_{B_{\bar{L}}}{}^2} = \sqrt{(0.0035)^2 + (0.0115)^2} = 0.012 mm$$

(5) Compute the uncertainty in λ.

$$\sigma_\lambda = \frac{2}{5}\sigma_l = \frac{2}{5}\times 0.012 = 0.0048mm$$

(6) Compute the uncertainty in *f*.

$$\sigma_f = \mu_{B_f} = \frac{\Delta_{Instr.}}{\sqrt{3}} = \frac{0.01}{\sqrt{3}} = 5.78Hz$$

(Note: Single measurement was performed for the frequency. The unit of the last digit is the instrument error for a digital apparatus.)

(7) Compute the relative uncertainty in the ultrasonic speed V_s.

$$\frac{\sigma_{V_s}}{V_s} = \sqrt{(\frac{\sigma_\lambda}{\lambda})^2 + (\frac{\sigma_f}{f})^2} = \sqrt{(\frac{0.0048}{10})^2 + (\frac{5.78}{35000})^2} = 0.00048$$

(8) Compute the uncertainty in *V*.

$$\sigma_{V_s} = \overline{V_s}\times\frac{\sigma_V}{V} = 350\times 0.00048 = 0.168$$

(9) Write the final result of ultrasonic speed.

$$V_s = \overline{V_s} \pm \sigma_{V_s} = (350 \pm 0.168)m/s$$

Appendix

(Scanned data sheets)

3.13.5 Experimental Data

Data Table 3.13-1 ***Purpose***: **To measure the ultrasonic sound wavelength with standing wave method**

Resonance frequency f = 35.00 kHz; Room temperature T = 18 ℃

Trial	1	2	3	4	5	6	7	8	9	10
l_i/mm	5.845	10.865	15.860	20.845	25.860	30.855	35.860	40.865	45.845	50.850

Data Table 3.13-2 ***Purpose***: **To measure the ultrasonic sound wavelength with phase comparison method**

Trial	1	2	3	4	5	6	7	8	9	10
L_i /mm	3.305	10.350	18.530	27.010	32.315	39.165	46.350	55.160	67.780	74.585

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