# Physics Lab Report

Experiment Title: Measuring the Ultrasonic Speed

Student Number: 2016200302027

Chinese Name: 郑长刚

Teaching Assistant: Yajing Chen

Instructor: Jing Wu

Date Performed: 9th November

UESTC Student Number: 2016200302027 Email: 1558241660@qq.com Date: 12th November

| Score |
|---|
| |

## Abstract (About 100 words, 3 points)

In this experiment we are aiming at calculate the speed of the ultrasonic speed as well as its wave length. For getting this results, we use loads of knowledge about wave and oscillation. It uses the method of the standing wave which can help us to identify if the wave is move n times of its wave length.

After this experiment, we got the results of the speed of the ultrasonic sound and the wave length of it by doing the experiment and follow the procedure which is written on the book. We record the data and calculate it and finally get our result.

Also, this experiment is tricky. It tells me that we can calculate the wave length of sound in a way which use the reflection and produce the standing wave. It successfully transfers a 'hard measure' variable to another form of physics quantity which can be measured in some way.

| Score |
|---|
| |

## Introduction (3 points)

Ultrasonic sound waves are longitudinal with frequencies greater than 20khz which exceeds the upper limit of the human hearing range. Because of their high frequency and corresponding short wavelengths, ultrasound is used in many different fields. Ultrasonic devices such as sonar are used to detect object and measure distances. Ultrasonic imaging (sonography is used in both veterinary medicine and human medicine. in the nondestructive testing of products and structures, ultrasound is used to detect invisible flaws. industrially, ultrasound is used for cleaning and for mixing, and to accelerate chemical processes.

After performing this experiment and analyzing the data, you should be able to:

- Understand the production of ultrasonic sound by piezoelectric transducers.
- 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)

**Determination of resonance frequency**

(1) Familiarize yourself with the function generator, the ultrasonic speed - measuring set - up, and the dual-trace oscilloscope set up the circuit as shown in fig 3.13-6.

(2) Turn on the oscilloscope and the function generator. Choose sinusoidal wave with frequency 35.000khz from the function generator. adjust the distance between the transmitter and the receiver to a bout 5 mm.

(3) Adjust the knobs in the panel to make the sine wave stand still on the oscilloscope screen.

(4) Tune the frequency of the sine wave from the function generator from 35,000khz to 45.000khz. We find that the sine wave on the screen is changing in frequency and amplitude when the amplitude of the received sine wave reaches the maximum, the frequency of the ultrasonic wave is found.

(5) Record the frequency on the function generator as the frequency of the ultrasonic sound wave.
Note: If you can't observe any wave signal on the screen, your receiver could be at the position of node of the standing wave. in that case you can move the receiver until a sine wave is observed.

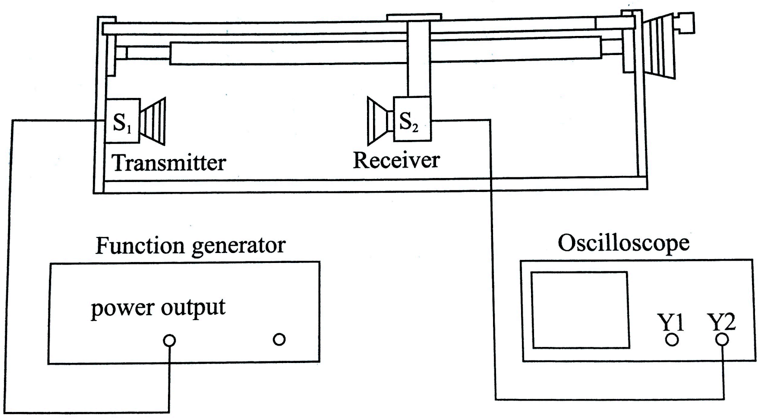



Fig. 3.13-6 Circuit configuration of the standing wave method

**Using standing wave method to measure the wavelength**

(1) Move the receiver slowly to increase the distance between the transmitter and the receiver. When the amplitude of the sine wave reaches the maximum. record the position and record it in data table 3.13-1 as $l_1$.

(2) Move the receiver to further increase the distance. when the amplitude reaches the next maximum again, record the position and continue the process to complete data table 3.13-1.

**Using phase comparison method to measure the wavelength**

(1) Set up the circuit as shown in fig 3.13-7.

(2) Turn the TIME/ DIV of the oscilloscope fully anticlockwise to x-y mode. Now, you can observe a lissajous pattern on the screen.

(3) Move the receiver until the lissajous pattern is changed to a line with positive slope as shown in fig 3.13-5. Record the position of the receiver as $l_1$ and enter it in data table 3.13-2 the receiver until the line with positive slope is visible on the screen again. Record the positions of the receiver to complete data table 3.13-2.

(4) Record the room temperature from the thermometer on the wall near the entrance.

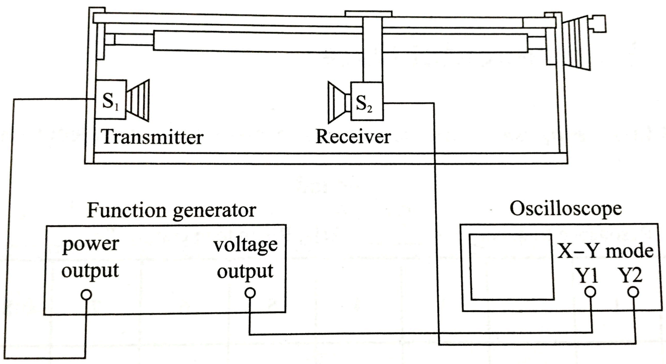



Fig. 3.13-7 The circuit configuration of phase comparison method

| 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*= 36.36 kHz; Room temperature *T*= 21.3 ℃;

| Trial | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| $l_i$ (mm) | 4.030 | 9.537 | 14.460 | 19.250 | 24.006 | 28.822 | 33.642 | 38.495 | 43.364 | 48.216 |

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) | 4.572 | 9.765 | 14.071 | 19.586 | 23.889 | 29.365 | 33.501 | 38.040 | 42.175 | 48.755 |

| Score |
| --- |
| |

## Discussion (More than 150 words, 5 points)

In this experiment, the answer is got in a tricky way as we use the standing wave use the lissajous pattern to measure the wave length which is generate by ultrasonic wave and the reflection wave. We can also use the precise micrometer caliper to measure the accurate distance between the two standing wave to generate.

Also, we use the basic knowledge about how the standing wave would happened and how property about the reflection and how we could use the lissajous pattern to know the phase difference of the phase different.

Besides, we need to focus on how to use the micrometer caliper especially how to read the result. To make sure our outcome precisely, we need to rotate it to one side for a small distance to make sure the gears bite well to ensure the precise of the result. After the measurement, we need to following the formulas and the theory to calculate the result.

| Score |
|---|
| |

## Conclusions (About 50 words, 2 points)

**The calculation steps (Including bringing in data) are in the appendix**

### 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.

$$V_0 = 331.30\times\sqrt{\frac{T}{T_0}} = 343.97(m/s) \quad (T_0\text{=273.15 K})$$

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

$$\overline{\lambda_s} = \frac{2}{25}[|l_{10}\text{-}l_5| + |l_9\text{-}l_4| + |l_8\text{-}l_3| + \cdots + |l_6\text{-}l_1|] = 9.700(mm)$$

(3) Compute the ultrasonic sound velocity.

$$\overline{V_s} = \overline{\lambda_s}\times f = 352.69\ (m/s)$$

(4) Compute the relative error.

$$E_s = \frac{\overline{V_s}\text{-}V_0}{V_0}\times 100\% = 25.4\%$$

### 6.2 Compute the ultrasonic sound speed measured by phase comparison method

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

$$\overline{\lambda_p} = \frac{1}{25}[|L_{10}\text{-}L_5| + |L_9\text{-}L_4| + |L_8\text{-}L_3| + \cdots + |L_6\text{-}L_1|] = 4.814\ (mm)$$

(2) Compute the ultrasonic sound velocity.

$$\overline{V_p} = \overline{\lambda_p}\times f \approx 350.07\ (\mathrm{ms})$$

(3) Compute the relative error.

$$E_p = \frac{\overline{V_p}\text{-}V_0}{V_0}\times 100\% \approx 1.74\%$$

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

(1) Compute the following difference in positions.

$L_1=|l_6-l_1|=24.792$ mm, $L_2=|l_7-l_2|24.105$ mm,

$L_3=|l_8-l_3|24.035$ mm, $L_4=|l_9-l_4|24.114$ mm,

$L_5=|l_{10}-l_5|=24.102$ mm,

$$\bar{L}=\frac{1}{5}(L_1+L_2+L_3+L_4+L_5)=24.230 \text{ mm}$$

(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 $\bar{L}$.

$$\mu_{A_{\bar{L}}}=\sqrt{\frac{\sum_{i=1}^{5}(L_i\text{-}\bar{L})^2}{5\times(5-1)}}=0.14130$$

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

$$\mu_{B_{\bar{L}}}=\frac{\Delta_{Instr.}}{\sqrt{3}}=2.9\times10^{-6}$$

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

(4) Compute the combined uncertainty in $L$.

$$\sigma_L=\sqrt{{\mu_{A_{\bar{L}}}}^2+{\mu_{B_{\bar{L}}}}^2}=0.14130$$

(5) Compute the uncertainty in $\lambda$.

$$\sigma_\lambda=\frac{2}{5}\sigma_l=0.05652$$

(6) Compute the uncertainty in $f$.

$$\sigma_f=\mu_{B_f}=\frac{\Delta_{Instr.}}{\sqrt{3}}5.7735\ (Hz)$$

(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 $V_s$.

$$\frac{\sigma_{V_s}}{V_s}=\sqrt{(\frac{\sigma_\lambda}{\lambda})^2+(\frac{\sigma_f}{f})^2}\approx0.0058$$

(8) Compute the uncertainty in $V$.

$$\sigma_{V_s}=\overline{V_s}\times\frac{\sigma_V}{V}=2.05$$

(9) Write the final result of ultrasonic speed.

$$V_s = \overline{V_s} \pm \sigma_{V_s} = (352.69 \pm 2.05)m/s$$

**The calculation steps (Including bringing in data) are in the appendix**

| Score |
|---|
| |

## References (1 points)

Some parts I write on this prelab which is reference from Wikipedia and Baidu.

Some parts of my report was got from the book (Introductory physics experiments for undergraduates, Haofu)

Some of the words and formulas are from materials on BB9. Calculations were down by my partner Yue and me Musk.

| Score |
|---|
| |

## Answers to Questions (6 points)

**(1) Two methods are used to measure the ultrasonic sound wavelength in this experiment. Which one is more accurate? Why?**

The second method.

In my opinion, the phase comparison method is more accurate when it compares to the standing wave method as the phase graph is more accurate when the pattern become as a line. It is easy to see if the pattern is shown as the line. However, when we use the standing wave method, (it is hard but) we need to make sure if the superposition reaches its maximum value because the pattern changes a lot when we adjust the apparatus a little. More than that, when we do this experiment, the shake of the table also would influence the result of the standing wave method a lot. So, I think the phase comparison method is more accurate.

**(2) How is it determined that the transmitter is in resonance?**

When we connect the apparatus, we just vary the frequency which is generated by the transmitter. We can receive the output voltage and get the pattern from the oscilloscope which is because the receiver forced vibration because of the ultrasonic that generated from the transmitter. Because we just change the vibration and just to find at which frequency, the vibration of the receiver reaching its maximum. So, at that time, the pattern(amplitude) of the outcome on the oscilloscope would be biggest and the resonance happened and that close to its inherent frequency at that moment.

Appendix

| Score |
|---|
| |

**(Calculations, 15 points)**

**Calculated by me and my partner.**

电子科技大学
University of Electronic Science and Technology of China

~~3.13.6.1~~ (m/s)

(1) $V_0 = 331.30 \times \sqrt{\frac{T}{T_0}} = 331.30 \times \sqrt{\frac{294.45}{273.15}} = 343.97$

(2) $\bar{\lambda}_s = \frac{2}{25}[|l_{10}-l_5|+|l_9-l_4|+|l_8-l_3|+\cdots|l_6-l_1|]$

$= \frac{2}{25}[|48.216-24.006|+|43.364-19.250|$

$+|38.485-14.460|+|33.642-9.537|$

$+|28.822-4.030|]$

$= 9.700\ (mm)$

(3) $\bar{V}_s = \bar{\lambda}_s \times f = 9.700 \times 10^{-3} m \times 36.36 \times 10^3 Hz$

$= 352.69\ m/s$

(4) $E_s = \frac{\bar{V}_s - V_0}{V_0} \times 100\% \approx \frac{352.69 - 343.97}{343.97} \times 100\% \approx 2.54\%$

3.13.6.2

(1) $\bar{\lambda}_p = \frac{1}{25}[|L_{10}-L_5|+|L_9-L_4|+\cdots|L_6-L_1|]$

$= \frac{1}{25}[|48.755-23.899|+|42.175-19.589|$

$+|38.040-14.071|+|33.501-9.765|$

$+|29.765-4.572|]$

$= 4.814\ mm$

地址：成都市建设北路二段四号 高新西区西源大道2006号 查询电话：83201114 邮政编码：610054（沙河校区） 611731（清水河校区）

1

(1) $\overline{V_p} = \overline{\lambda_p} \times f = 350.07$ m/s

(2) $E_p = \frac{\overline{V_p} - V_0}{V_0} \times 100\% \approx 1.74\%$

3.13.6.3

(1) $L_1 = |l_6 - l_1| = |28.822 - 4.030| = 24.792$ (mm)

$L_2 = |l_7 - l_2| = |33.642 - 9.537| = 24.105$ (mm)

$L_3 = |l_8 - l_3| = |38.495 - 14.460| = 24.035$ (mm)

$L_4 = |l_9 - l_4| = |43.364 - 19.250| = 24.114$ (mm)

$L_5 = |l_{10} - l_5| = |48.216 - 24.006| = 24.102$ (mm)

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

$= \frac{1}{5}(24.792 + 24.105 + 24.035 + 24.114 + 24.102)$

$= 24.230$ (mm)

(2) $\mu_{A\overline{L}} = \sqrt{\frac{\sum_{i=1}^{5}(L_i - \overline{L})^2}{5 \times (5-1)}}$

$$= \sqrt{\frac{(24.792-24.230)^2 + (24.105-24.230)^2 + (24.035-24.230)^2 + (24.114-24.230)^2 + (24.102-24.230)^2}{5 \times 4}}$$

$\approx 0.14130$ ~~(mm)~~

电子科技大学
University of Electronic Science and Technology of China

(3) $\mu_{B_L} = \frac{\Delta_{instr.}}{\sqrt{3}} = \cancel{0.005}\ \frac{5\times10^{-6}m}{\sqrt{3}} \approx 2.9\times10^{-6}$

(4) $\delta_L = \sqrt{\mu_{A_L}^2 + \mu_{B_L}^2} \approx 0.14130$

(5) $\delta_\lambda = \frac{2}{5}\delta_L = 0.05652$

(6) $\delta_f : \mu_{Bf} = \frac{\Delta_{instr.}}{\sqrt{3}} = \frac{0.01\times10^{3}\ Hz}{\sqrt{3}} \approx 5.7735\ Hz$

(7) $\frac{\delta_{V_s}}{V_s} = \sqrt{\left(\frac{\delta_\lambda}{\lambda}\right)^2 + \left(\frac{\delta_f}{f}\right)^2} = \sqrt{\left(\frac{0.05625}{9.700}\right)^2 + \left(\frac{5.7735}{36.36\times10^{3}}\right)^2}$
$\approx 0.0058$

(8) $\delta_{V_s} = \overline{V_s} \times \frac{\delta_V}{V} = \cancel{2.0456}\ 2.05$

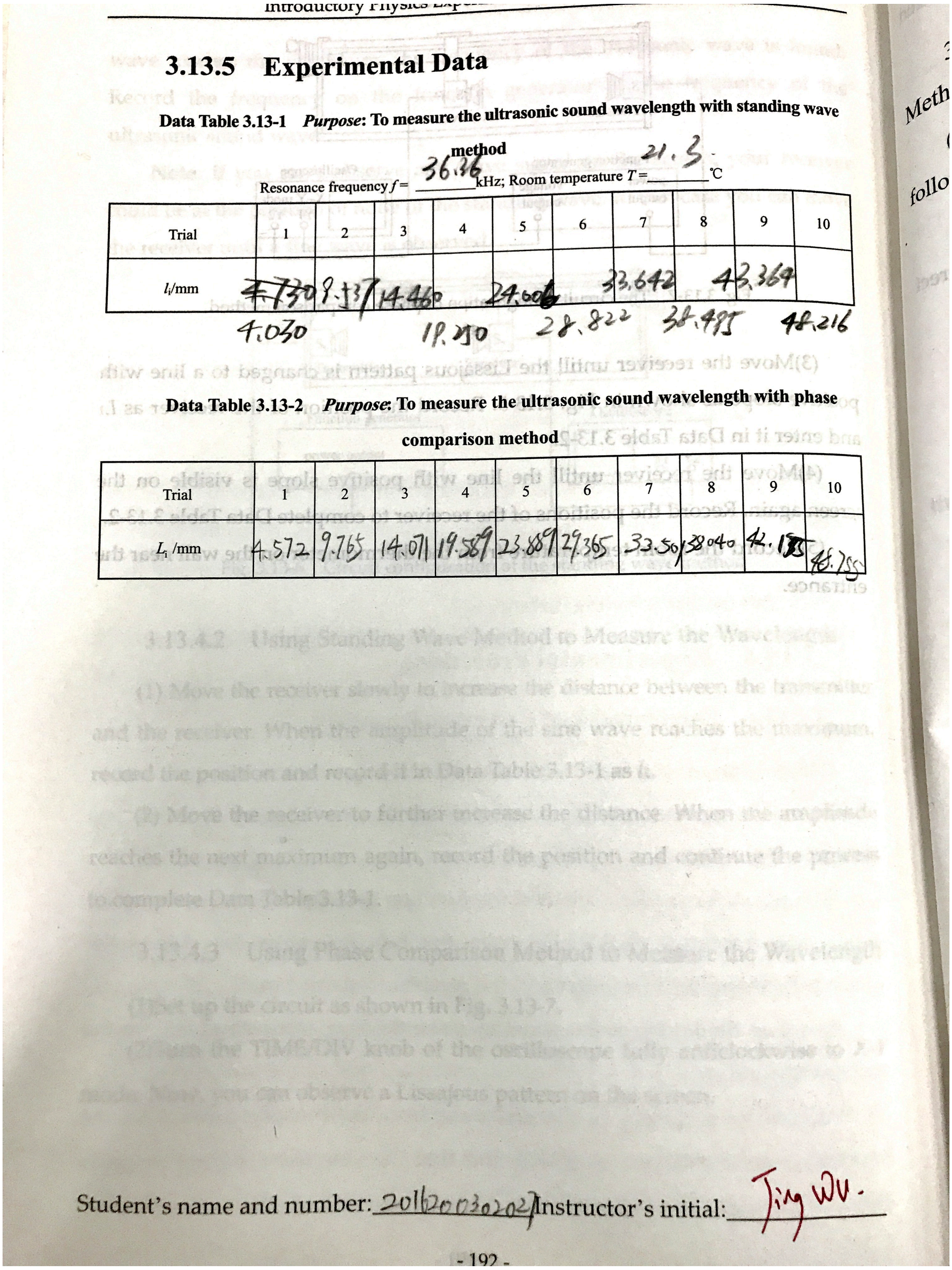
(9) $V_s = \overline{V_s} \pm \delta_{V_s} = (352.69 \pm 2.05)\ m/s$



Calculated by me and my partner.

# Appendix

## (Scanned data sheets)



Introductory Physics Exp...

### 3.13.5 Experimental Data

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

Resonance frequency $f$ = 36.36 kHz; Room temperature $T$ = 21.3 ℃

| Trial | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| $l_i$/mm | ~~4.730~~ | 9.137 | 14.460 | | 24.006 | | 33.642 | 43.364 | | |

4.030 19.290 28.822 38.495 48.216

**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 | 4.572 | 9.765 | 14.071 | 19.589 | 23.889 | 29.365 | 33.50 | 38.040 | 42.185 | 48.755 |

Student's name and number: 2016200302027 Instructor's initial: Jing Wu.

- 192 -