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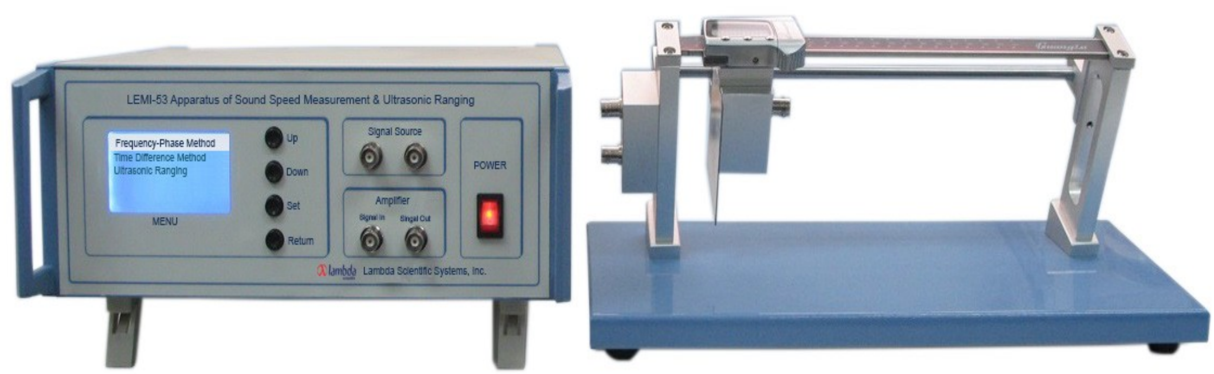
*Construct, Conduct & Comprehend Physics Experiments*

# LEMI-53 Apparatus of Sound Speed Measurement and Ultrasonic Ranging




- High performance ultrasonic sensor
- Simple structure, stable and reliable
- Multiple experiments

The propagation speed of sound waves is an important physical quantity. The measurement of sound speed is widely applicable in ultrasonic ranging, positioning, measurement of liquid flow rate, material's elastic modulus and changes of gas temperature. Ultrasonic emission and reception is also one of the important means of anti-theft, monitoring and medical diagnosis.

This experimental apparatus of sound speed measurement and ultrasonic ranging is specially designed for educational training in teaching labs. It can measure the speed and the wavelength of a sound wave propagating in the air, and perform an experiment on ultrasonic ranging, so that students can better understand the basic principles and experimental methods of wave physics.

LEMI-53 apparatus has the following features:

1. A compact high efficient ultrasonic sensor is used. It has a metal housing shield of strong anti-interference ability with strong reflection and reception signal;
2. The apparatus is simple in structure, easy in operation and reliable in data reading.

# Experiments

1. Measure the speed of sound wave propagating in the air by the method of resonant interference.
2. Measure the speed of sound wave propagating in the air by the method of phase comparison.
3. Measure the speed of sound wave propagating in the air by the method of time difference.
4. Measure the distance of a barrier board by the method of reflection.

# Parts & Specification

| Description | Specifications |
|---|---|
| Sine wave signal generator | Frequency range: 30 ~ 50 kHz; resolution: 1 Hz |
| Ultrasonic transducer | Piezo-ceramic chip; oscillation frequency: 40.1 ± 0.4 kHz |
| Vernier caliper | Range: 0 ~ 200 mm; accuracy: 0.02 mm |
| Experimental platform | Base board size 380 mm (L) × 160 mm (W) |
| Measurement accuracy | Sound velocity in air, error < 2% |

**1. Measure sound speed using resonant interference method**

Table 1 Data of resonant interference method ($T$ = *26.1 °C*, $f$ = *40.070 KHz*)

| *No. (i)* | *Li (mm)* | No. (*i*) | *Li (mm)* | *ΔLi (mm)* | $\overline{\Delta Li}$*(mm)* |
|---|---|---|---|---|---|
| 1 | 3.60 | 11 | 47.41 | 43.81 | |
| 2 | 8.03 | 12 | 51.78 | 43.75 | |
| 3 | 12.32 | 13 | 56.02 | 43.70 | |
| 4 | 16.83 | 14 | 60.03 | 43.20 | |
| 5 | 21.09 | 15 | 64.35 | 43.26 | 43.31 |
| 6 | 25.63 | 16 | 68.74 | 43.11 | |
| 7 | 29.95 | 17 | 73.08 | 43.13 | |
| 8 | 34.42 | 18 | 77.47 | 43.05 | |
| 9 | 38.72 | 19 | 81.77 | 43.05 | |
| 10 | 43.11 | 20 | 86.17 | 43.06 | |

Average $\overline{\lambda} = 43.31 \times \frac{1}{5} = 8.662mm$

Sound speed: $V = 40.070 \times 8.662 = 347.1 m/s$.

At temperature T = 26.1 °C, sound speed in dry air is $V_0$=*347.3 m/s*. The experimental result has an error 0.06%.

**2. Measure sound speed using phase method**

Table 2 Results of phase method ($T$ = *26.0 °C*, $f$ = *40.070 KHz*)

| *No. (i)* | *Li (mm)* | No. (*i*) | *Li (mm)* | *ΔLi (mm)* | $\overline{\Delta Li}$*(mm)* |
|---|---|---|---|---|---|
| 1 | 29.95 | 11 | 73.28 | 43.33 | |
| 2 | 34.30 | 12 | 77.63 | 43.33 | |
| 3 | 38.64 | 13 | 81.91 | 43.27 | |
| 4 | 42.97 | 14 | 86.25 | 43.28 | |
| 5 | 47.32 | 15 | 90.65 | 43.33 | |
| 6 | 51.66 | 16 | 94.92 | 43.26 | 43.29 |
| 7 | 55.96 | 17 | 99.23 | 43.27 | |
| 8 | 60.28 | 18 | 103.57 | 43.29 | |
| 9 | 64.61 | 19 | 107.90 | 43.29 | |
| 10 | 68.98 | 20 | 112.22 | 43.24 | |

Average $\overline{\lambda} = 43.29 \times \frac{1}{5} = 8.658mm$

Sound speed $V = 40.070 \times 8.658 = 346.9 m/s$.

At temperature T = 26.0 °C, sound speed in dry air is $V_0$=*347.2 m/s*. The experimental result has an error 0.09%.

**3. Measure sound speed using time difference method**

Table 3 Results of time difference method ($T$ = *23.8 °C*)

| *L (mm)* | 0 | 10.08 | 20.20 | 30.10 | 40.29 | 50.19 | 60.52 | 70.23 | 80.21 |
|---|---|---|---|---|---|---|---|---|---|
| *t (us)* | 160 | 196 | 229 | 256 | 284 | 311 | 341 | 368 | 395 |
| *L (mm)* | 90.29 | 100.07 | 110.19 | 120.27 | 130.42 | 140.3 | 150.15 | 160.29 | 170.32 |
| *t (us)* | 424 | 451 | 480 | 518 | 547 | 575 | 602 | 630 | 659 |

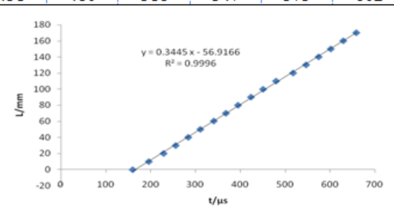



Figure 3 Plot of relationship between distance (L) and time difference (t)

By straight line fitting, we got slope, it is sound speed $V = 0.345 mm/\mu s = 345 m/s$.

At temperature T = 23.8 °C, sound speed in dry air is $V_0$=*345.9 m/s*. The experimental result has an error 0.26%.

**4. Measure barrier board distance by reflection method**

Since the transmitting and receiving ends of the ultrasonic probe are separated by a certain distance, as shown in Figure 4, the measured distance $L=x/\cos(\theta)$ is larger than the actual distance x. The error reduces with x increasing. For ultrasonic ranging of close distance, the measurement results must be corrected.

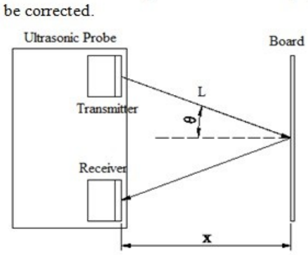



Figure 4 Schematic of the actual distance of ultrasonic ranging

Table 4 Comparison of measured and actual distances

| *L (mm)* | 0 | 10.23 | 20.07 | 30.37 | 40.03 | 50.16 | 60.18 | 70.26 | 80.27 |
|---|---|---|---|---|---|---|---|---|---|
| *x (mm)* | -1 | 9 | 19 | 30 | 39 | 49 | 60 | 69 | 79 |
| *L (mm)* | 90.18 | 100.05 | 110.3 | 120.07 | 130.42 | 140.62 | 150.49 | 160.1 | 170.29 |
| *x (mm)* | 89 | 100 | 109 | 119 | 129 | 140 | 150 | 160 | 170 |

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