Note( $303.11^{2\ ***}$)

جامعة بيرزيت

BIRZEIT UNIVERSITY **Physics Department**

**Physics 211**

# Speed of sound in air

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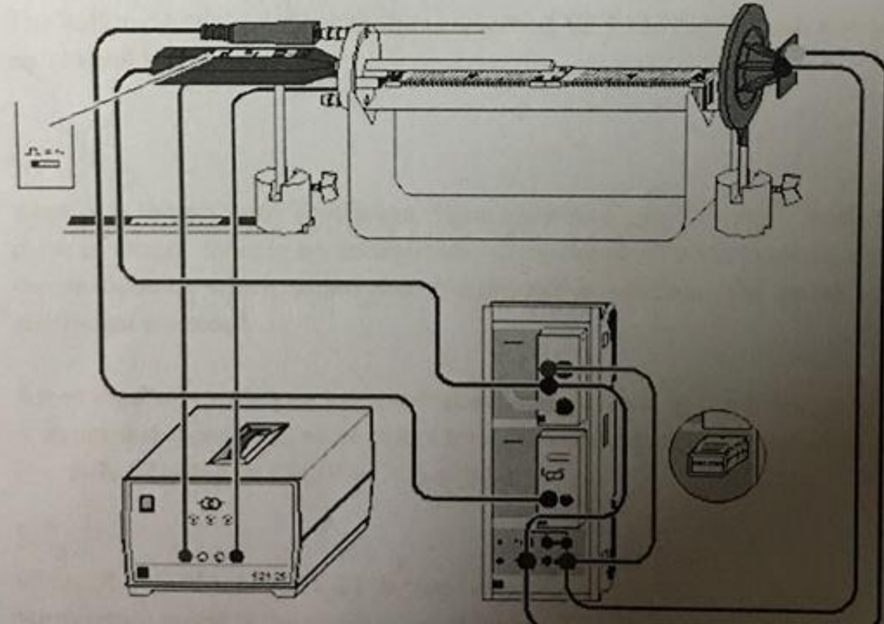

Note( $303.11^{2\,***}$)

**bstract:**

- The aim of this experiment: To find the speed of sound in air at room temp. & at Zero C & to find the adiabatic coefficient at 0 C. Also to study the effect of temperature on the speed of sound.
- The method used:

By using the computer that is connected to the system to calculate & measure the time & the speed of sound, & by using a thermometer & by changing the temp (T) to find the effect of T on the speed of sound in air

- The main results:

At room Temp => C = 354 ∓ 6 m/s

At zero C° => C = 303.11 m/s

The adiabatic coefficient at 0 C $\gamma = 1.2$

**Theory:**

Sound waves are mechanical waves which need medium to transfer. They transfer as pulses or compression waves (longitudinal wave). The speed of sound waves depends on the properties (compressibility and density) and the temperature of the medium.

It was found that the speed of sound in air depends on its ability to be compressed (Bulk modulus $\kappa$ ) and its density $\rho$ as in eq. (1)

$$c = \sqrt{\frac{\kappa}{\rho}} \tag{1}$$

The bulk modulus is related to the pressure of air $P$ via the relation $\kappa = \gamma P$, thus eq. (1) will be

$$c = \sqrt{\gamma \frac{P}{\rho}} \tag{2}$$

where $\gamma$ is the adiabatic coefficient. From a classical point of view, when a sound pulse is formed there is no enough time to exchange heat between the pulse and the surrounding which means that this process is adiabatic and so the adiabatic coefficient is needed.

Air at standard conditions of temperature and pressure, at room temperature and at atmospheric pressure, as be safely treated as ideal gas. Using the ideal gas law $P = NRT/V$ and $\rho = NM/V$ eq. (2) will be

$$c = \sqrt{\gamma \frac{RT}{M}} \tag{3}$$

where $R = 8.315\ J/(mol.K)$ is the molar gas constant, T is the absolute temperature and $M$ is the molar mass of the air. The molar mass of dry air is about $0.0289\ Kg/mole$. $N$ and $V$ are the number of moles and the volume of the gas

Note( $303.11^{2}$ ***)

time at any temperature the speed of sound will be evaluated immediately as you defined $\mathbf{c} = \boldsymbol{s/\Delta t_{A1}}$ in the setting at first.

**Safety notes:**

The plastic tube of the apparatus for sound and speed can be destroyed by excessive temperatures.

- Do not heat it above 80 °C.
- Do not exceed the maximum permissible voltage of 25 V (approx. 5 A) for the heating filament.

**Data and Calculations:**

- Speed of sound at room temperature

| $n$ | $s_1 = 0.410 \quad \pm 0.001 \quad m$ | $s_2 = 0.195 \quad \pm 0.001 \quad m$ |
|---|---|---|
| | $\Delta t_{A1_{s1}}(s)$ | $\Delta t_{A1_{s2}}(s)$ |
| 1 | 0.0009330 | 0.0003258 |
| 2 | 0.0009362 | 0.0003267 |
| 3 | 0.0009340 | 0.0003330 |
| 4 | 0.0009340 | 0.0003350 |
| 5 | 0.0009415 | 0.0003215 |
| *Avg.* | $t_{1,avg} = 0.0009358 \pm 0.0000015\,s$ | $t_{2,avg} = 0.0003284 \pm 0.0000025\,s$ |

- $\Delta s = s_1 - s_2 = 0.215$
- $\Delta t = t_{1,avg} - t_{2,avg} = 0.0006074$
- $c = \frac{\Delta s}{\Delta t} = 353.967731 \ m/s$
- $\frac{\Delta c}{c} = \frac{\Delta s_1 + \Delta s_2}{\Delta s} + \frac{\Delta t_1 + \Delta t_2}{\Delta t}$

$$\Delta c = c * \left(\frac{\Delta s_1 + \Delta s_2}{\Delta s} + \frac{\Delta t_1 + \Delta t_2}{\Delta t}\right)$$

Temp = 29C°

$$= 353.97\left(\frac{0.001 + 0.001}{0.215} + \frac{0.0000015 + 0.0000025}{0.0006074}\right)$$

$= 5.62 \ m/s \quad m/s$

$= 6 \ m/s$

$C = 354 \mp 6 \ m/s$

Note( 303.11$^{2\ ***}$)

| $\Delta t_{A1_{s1}}(s)$ |
|---|
| 0.0009385 |
| 0.0009442 |
| 0.0009423 |
| 0.0009455 |
| 0.0009435 |
| $\Delta t_{A1,avg}$ = 0.0009428 ± 0.0000012 s |

$s = c.\Delta t_{A1}$ = 0.33372078 m

- Take a measurement every 5 °C

| $n$ | $\vartheta$ °C | $c\ (m/s)$ |
|---|---|---|
| 1 | 30.1 | 322.061 |
| 2 | 35.6 | 324.939 |
| 3 | 40.8 | 330.761 |
| 4 | 45.5 | 330.670 |
| 5 | 50.2 | 338.409 |
| 6 | 55.5 | 339.943 |
| 7 | 60.0 | 341.783 |
| 8 | 65.1 | 344.037 |
| 9 | | |
| 10 | | |

The sound velocities are plotted in the **Temperature** display as a function of the temperature while the measurements running. By fitting a straight line eq. (4) can be confirmed easily. From the graph**$c$ vs. $\vartheta$** find

- The speed of sound at zero Celsius = 303.11 m/s (y-int)
- The adiabatic coefficient at zero Celsius

$$\gamma = c^2(0)\left(\frac{\rho(0)}{p(0)}\right) = 303.11\left(\frac{1.292}{1.013\times10^5}\right) = 1.17 = 1.2$$

Note( $303.11^2$ ***)

| n | $C^0$ | C(m/s) |
|---|---|---|
| 1 | 30.1 | 322.061 |
| 2 | 35.6 | 324.939 |
| 3 | 40.8 | 330.761 |
| 4 | 45.5 | 330.670 |
| 5 | 50.2 | 338.409 |
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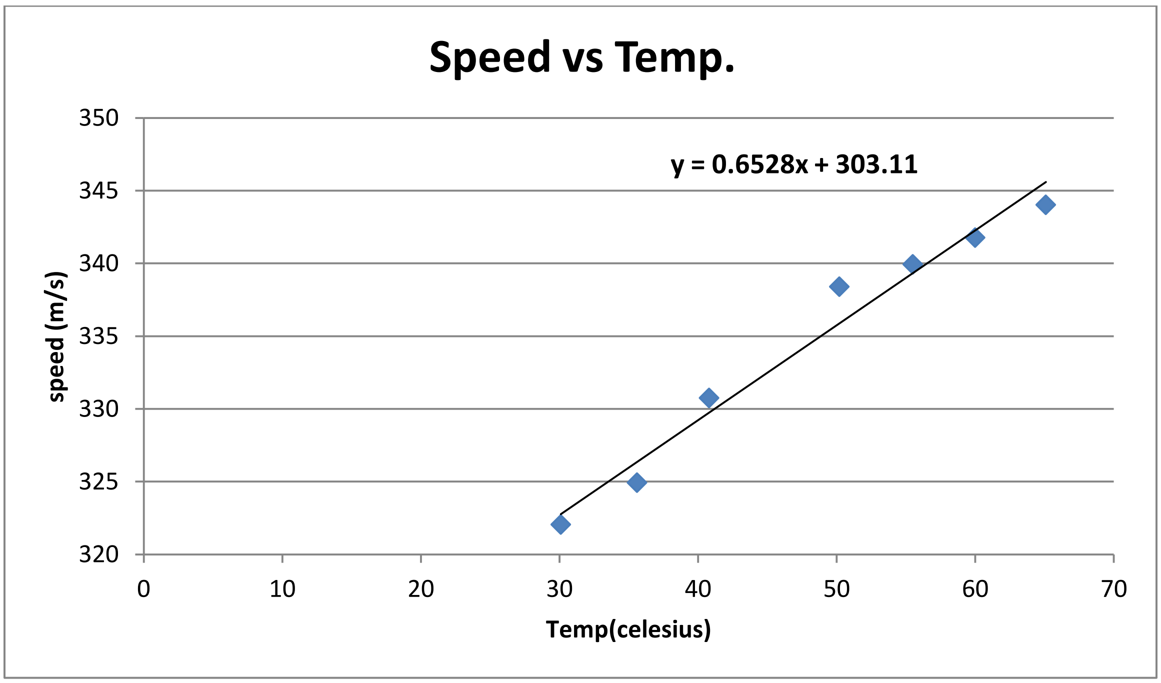


| | slope | y-int |
|---|---|---|
| value | 0.652767 | 303.1078 |
| error | 0.050365 | 2.502101 |

Note( $303.11^{2\ ***}$)

| | |
|---|---|
| At room temperature | $c = 354 \pm 6$ m/s |
| At zero Celsius | $c = 303.11$ m/s |
| The adiabatic coefficient at zero Celsius | $\gamma = 1.2$ |

Sound waves are longitudinal mechanical waves that results from the back & forth vibration of the particles of the medium through which the sound wave is moving.

The temperature of the medium (air) affect the speed of sound because heat increase makes the air molecules to have higher kinetic energy so they can vibrate faster & so transfer the sound wave more quickly.

In this experiment, we found the speed of sound at 29 °C (room Temp.) to be $C_{exp} = 354$ m/s & $C_{theo.} = 331.3 + 0.606(29) = 348.9 = 349$ m/s

$D = |354 - 349| = 5 < 2\Delta C$ (accepted)

At Zero °C

$C_{exp} = 303.11$ m/s , $C_{theo.} = 331.3$ m/s

our result has a deviation of nearly 20 (m/s) & this indicates that the errors occured in readings in the experiment affected the results significantly. specially the position of the straight line which we took its y-int to find the speed at Zero °C.

There were many sources of erros:

- The sounds in the lab (it wasn't so quiet).
- The temperature of the room was not ~~near~~ 20 °C it was higher.
- The system that measures the speed was not very stable
- ~~The~~ we had to take a large number of measumments in order to obtain more accurate results but this cannot be done because we cannot raise the temp. more than 65 °C

Note( 303.11² ***)