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Measuring the Speed of Sound Using Oscilloscope and Buzzers

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Abstract: The speed of sound in air can be measured by means of an oscilloscope recording the signals of two receivers, which have in front of them an emitter that can be moved. The method is simple and suitable for a student laboratory. The aim of this approach is not only the measurement of the phase velocity of a wave, but also to trigger interest among students about the use of oscilloscopes.

Keywords: Sound, Waves, Phase Velocity, Physics class.

1. Introduction

The speed of sound in air can be measured by several methods. Some of them are quite appealing for students, such as that proposed in [1] and based on echoes produced by popping balloons. The authors of [1] are using a computer with Vernier LabQuest and Audacity for sound recording and editing. Other methods are based on the distance travelled by waves, using two loudspeakers and a receiver, such as that proposed in [2]. However, we can determine the speed of sound in air by using an oscilloscope recording the signals of two receivers which have in front of them an emitter that can be moved. This method, that we are here proposing, is simple and suitable for a student laboratory. The aim of its approach is not only the determination of the phase velocity of sound waves, but also that of stimulating the interest of students on using oscilloscopes.

As we did in other papers [3-6], we are also considering the cost of experiments. The experience can be costless; in fact, it is quite easy to have the laboratory already equipped with a function generator and an old oscilloscope, may be abandoned because signal acquisition boards on PC are preferred. Moreover, since oscilloscopes and function generators can be used for investigating circuits too, the cost of studying the phase velocity of waves can be shared with those of other experiments.

2. Sound propagation

Waves propagate through compressible media longitudinally and transversally. In fact, it is usual to consider "sound" only the longitudinal waves moving in air and water. The sound waves are generated by vibrating elements in some devices: we can use buzzers or beepers for instance, which are small and low-cost piezoelectric devices, having membranes that can be get into a vibrating motion by an oscillating electric field. These devices create waves in the surrounding medium, which propagate away from them at the speed of sound. The sound can be recorded by a receiver. Due to its nature, a beeper can be a receiver too, being its membrane a piezoelectric sensor, creating an electric signal when put in vibration by the sound.

The speed of sound depends on the medium the waves pass through. The first significant effort towards the measure of this speed was made by Isaac Newton. He believed that the speed of sound in a particular substance was equal to the square root of the pressure acting on it divided by its density. French mathematician Pierre Simon Laplace corrected the Newton's formula, by deducing that the propagation of sound was not an isothermal process but adiabatic, and then $c=\sqrt{\gamma P/\rho}$, which is also known as the Newton-Laplace equation [7]. In this equation, c is the speed of the sound, P the pressure, ρ the density and γ the adiabatic constant.

3. Experimental Set-up

The experiment consists of measuring the phase velocity of sound waves through the use of simple tools (an oscilloscope, a function generator and three piezoelectric buzzers). Two piezoelectric buzzers are connected to the oscilloscope so that they are working as receivers, while the third is connected to the signal generator and works as an emitter of sound. To trigger the oscilloscope we use the function created by the generator, which is controlling the sound emitter. The oscilloscope is a 20MHz Kenwood CS-4025. The function generator is a Topward 8112. Oscilloscope and generator are shown in the Figure 1. The receivers are fixed on a suitable structure (see Figure 2). Let us have the fuction generator outputting a sinusouidal signal at 14 kHz. On the monitor of the oscilloscope, we will see

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the two signals received by the piezoelectric devices; such signals can be in phase or out of phase. In the Figure 3 for instance, we can see the oscilloscope showing the two signals out of phase, whereas in the Figure 1, they are in phase. If the signals are in phase, it means that the difference of the two distances between emitter and receivers is zero or a multiple of the wavelength of the sound, as we will explain in the next section.

4. Theory

In the Figure 2 we can see the set-up of emitter and receivers. In order to obtain good measures, it is better to have the the hole of the emitter on the same plane of the holes of receivers: this is obtained using a holder (here a pen, which is also good to move the emitter). The distance between receivers is 8.7 cm.

Let us assume the emitter producing a spherical monochromatic wave. In an arbitrary direction of the space, this wave is given by:

$$\Psi(r,t)=\frac{A}{r}e^{-i(kr-\omega t)} \qquad (1)$$

A is a constant, r the distance, $k=2\pi/\lambda$, $\omega=2\pi c/\lambda$. λ is the wavelength and c the phase velocity of the wave. Let us have $\vec{r}$ giving the position vector which defines a point in the three-dimensional space from the emitter. The phase is $\phi=\vec{k}\cdot\vec{r}-\omega t=kr-\omega t$, since for a spherical wave, vector $\vec{k}$ is parallel to $\vec{r}$. Let us consider two directions $\vec{r}_1,\vec{r}_2$, those going from the emitter to the two receivers (Figure 2). We have the phase difference $\Delta\phi=\phi_1-\phi_2=kr_1-kr_2$. Here, r_1 is the distance emitter – receiver R_1 and r_2 the distance emitter – receiver R_2. The signals of the two receives are in phase when $\Delta\phi=0$ or $\Delta\phi=k(r_1-r_2)=2\pi n$, with n integer. We have this condition when $\Delta r=|r_1-r_2|=n\lambda$.

5. Data analysis and discussion

To have the abovementioned condition, we move the emitter. When we see the two signals in phase on the oscilloscope display (see Figure 1 and 3), we have $\Delta r=|r_1-r_2|=n\lambda$. In our experimental set-up we found, for instance, the following cases:

$$\begin{aligned} r_1 &= 8.0\,cm;\ r_2=10.4\ cm;\ \Delta r=2.4\ cm \\ r_1 &= 6.4\,cm;\ r_2=8.8\ cm;\ \Delta r=2.4\ cm \end{aligned} \qquad (2)$$

The speed of the sound is given by $c=\Delta r/T$, where T is the period of the wave. Let us read the period on the oscilloscope monitor: we had $T=0.7\times10^{-4}\ s$.

From the two cases (2), which correspond to a difference of one wavelength, we have the speed $c=343$ m/s. In fact, this value has a large uncertainty, of $\pm4\%$, because of the uncertainty of Δr, which is $\pm0.1cm$. To have a lower uncertainty, it is necessary a better arrangement; in particular, we need to improve the set-up holding emitter and sensors and the measurement of distances. To improve the signals on oscilloscope, it is necessary to remove the reverberant field, due to reflections from the table or other objects

Let us conclude telling that the aim of this experiment is not only the measurement of the speed of sound. In fact, we are interested to show to students, besides the phase velocity of waves, the phase shift that can be obtained when waves are following different paths in the space. A good way to do this is by using oscilloscopes, because phases can be immediately appreciated on their monitors.

References

1. A. Berg and M. Courtney, Echo-Based Measurement of the Speed of Sound, 2011, http://arxiv.org/ftp/arxiv/papers/1102/1102.2664.pdf
2. J. Silver, Using Waves to Measure the Speed of Sound http://www.education.com/science-fair/article/waves-measure-speed-sound/
3. A.C. Sparavigna, The Oscillations of Heavy Springs Discussed for a Student Laboratory, The International Journal of Sciences, 2013, Volume 2, Issue 10, Pages 94-99.
4. A.C. Sparavigna and R. Marazzato, Experiments on Radioactivity in a Student Laboratory, The International Journal of Sciences, 2014, Volume 3, Issue 2, Pages 7-11.
5. A.C. Sparavigna, An Ancient Rangefinder for Teaching Surveying Methods, Engineering, 2012, Volume 4, Issue 9, Pages 578-582.
6. A.C. Sparavigna, Measuring the Thermal Diffusivity in a Student Laboratory, Engineering, 2012, Volume 4, Issue 5, Pages 266-271.
7. B.S. Finn, Laplace and the Speed of Sound, Isis, 1964, Volume 55, Issue 179, Pages 7-19.

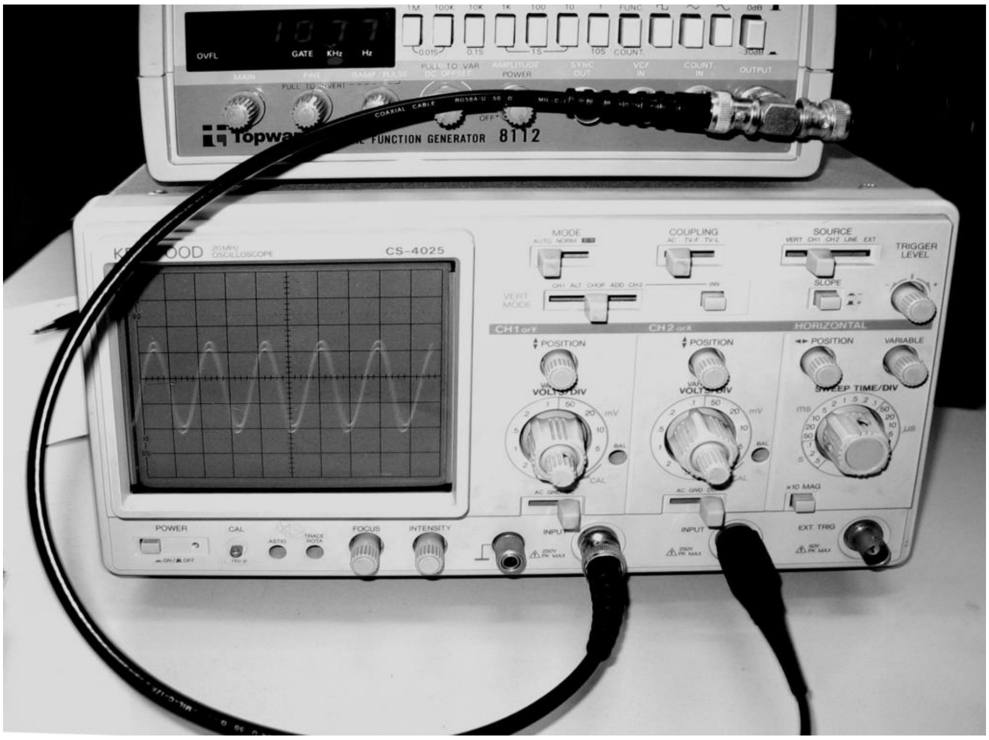

Figure 1 - The oscilloscope is a 20MHz Kenwood CS-4025. The function generator is a Topward 8112. Two piezoelectric buzzers are connected to the oscilloscope so that they are working as receivers, while the third is connected to the signal generator and works as a source of sound. To trigger the oscilloscope, we use the function created by the generator, which is controlling the sound emitter. The monitor is showing in-phase signals.

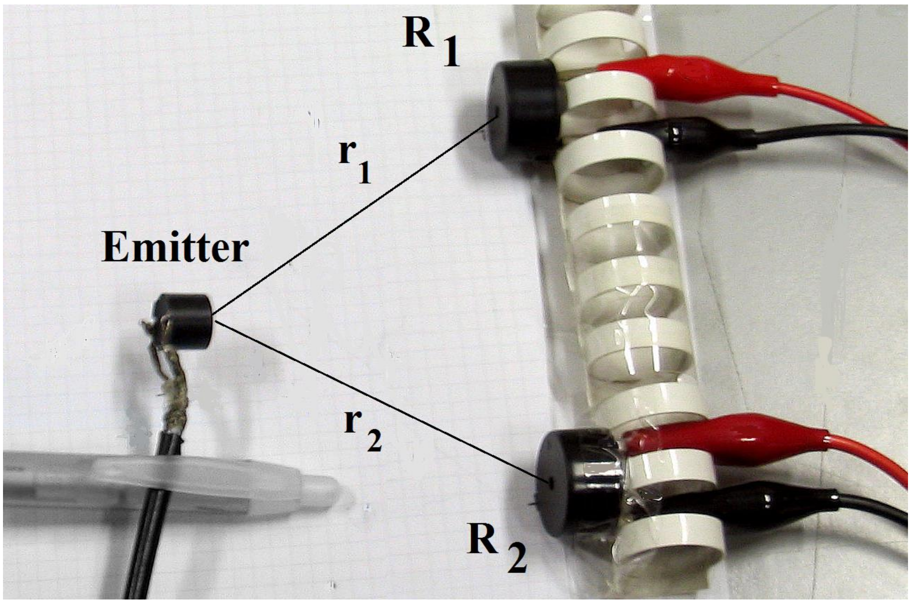

Figure 2 - The piezoelectric receivers are fixed on a suitable structure, whereas the emitter can be moved. Here the distance between receivers is 8.7 cm. On the monitor of the oscilloscope we see the two signals: they can be in phase or out of phase. If the signals are in phase, the difference of the two distances r_1 and r_2, between emitter and receivers, is zero or a multiple of the wavelength.

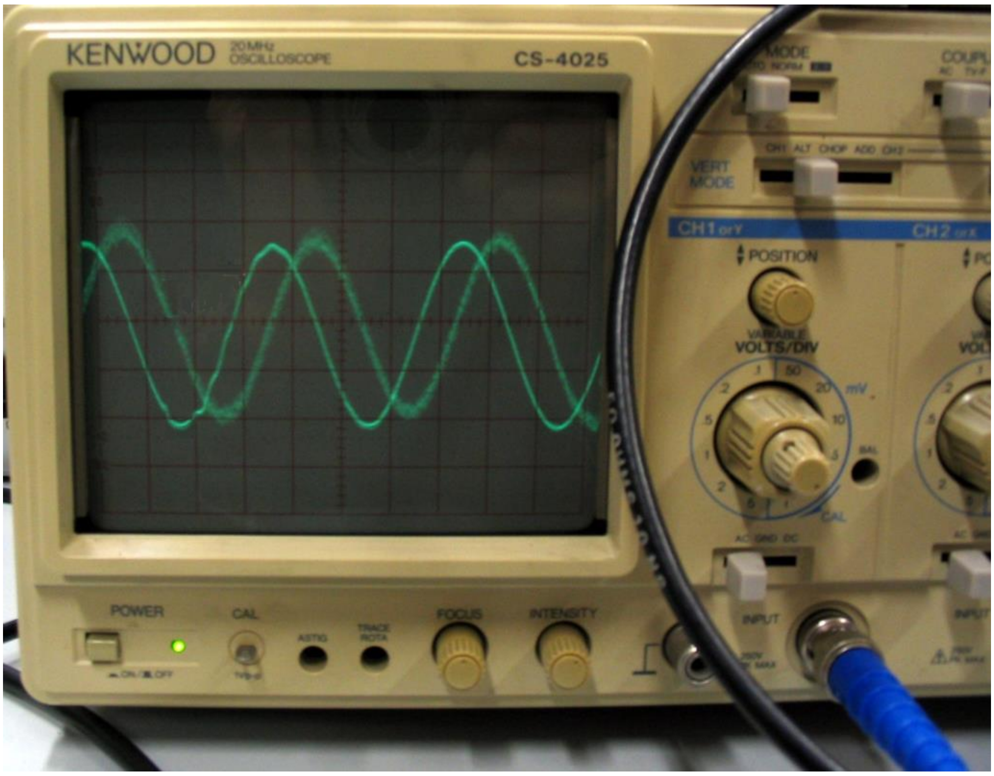

Figure 3 - The oscilloscope is showing two signals out of phase, coming from the receivers.