Alternative setup for estimating reliable frequency values in a ripple tank

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***Abstract*—In this paper, we introduce an innovative, low-cost and easy experimental setup to be used in a traditional ripple tank when a frequency generator is unavailable. This configuration was carried out by undergraduate students. The current project allowed them to experiment and to study the relationship between the wavelength and the oscillation period of a mechanical wave, among other things. Under this setup, students could evaluate the mechanism not only qualitative but also in a quantitative fashion with a high degree of confidence. The results obtained for the propagation speed of the mechanical waves in different media with this alternative design coincided with those acquired using a commercial device designed for this purpose.**

***Keywords*—Ripple tank, oscillations and mechanical waves, frequency generator, photogate.**

I. Introduction

The thorough understanding beyond theory is insufficient in the absence of hands-on activities. This problem of Physics learning does not let the students minds grow.
One of the most used devices by teachers and students to approach the study of oscillatory movements and phenomena of reflection, refraction, interference and diffraction is the *ripple tank*. This device is highly used as a qualitative demonstration because it allows one to visualize the wave propagation as well as its properties in an elementary physics course, easily. In recent years researchers in the education area support the idea of students centered real learning achievements. In this context, students are the main characters and executors of their knowledge process, avoiding staying only in descriptive stages. [1].

In this work, we propose a low-cost alternative experimental device for facilitating the understanding of the experimental procedure to study the quantitative relationship between the wavelength and the period of a mechanical wave. This new apparatus was designed and implemented by high school students in the absence of a frequency generator in the laboratory. Finally, we compared and validated our results using a commercial frequency generator designed for teaching labs. Indirect and reliable oscillation frequency measurements were computed for estimating the propagation velocity of a mechanical wave in different media.

The goal of this paper goes beyond the relationship study between two physical magnitudes. On the one hand, the design and presentation of a reliable experimental device, to obtain the frequency oscillation of a mechanical wave, involves the understanding not only of the experimental procedure but also the concepts participating in each stages. On the other hand, the lack of a commercial frequency generator, encourages students to use their creativity and ingenuity to obtain the desired magnitude with the available instruments in the laboratory.

The present effort is organized as follows. First, Section II describes the configuration of the experiment and measurements. Then, Section III presents the results of the calibration process as well as the performance of the proposed device. Finally, Section IV concludes the article and proposes new avenues for research.

II. Experimental setup and measurements

A ripple tank, depicted in Figure 1, consists of a rectangular tray with a transparent bottom. A light source is placed above the tray where a liquid is poured (the volume of liquid in the tray was 750 *ml*, and its depth was a thin layer of (4.694 $\pm$ 0.002) *mm*). A horizontal metal strip produced straight parallel waves. Therefore, when the liquid was mechanically disturbed the wave propagation could be seen. The horizontal bar was suspended by springs so that the bar was moved up and down by the vibrations of a small electric motor. Thus, we were able to obtain continuous ripples. A variable voltage source in the motor circuit controlled the speed and hence the frequency of the generated waves. The light source produced a bright and dark wave pattern on the white screen below the ripple tank. Then, we used a stroboscope (a CD with a hole) to show, for a certain speed of rotation, the static waves. Accordingly, the pattern formed by continuous waves seemed to be stationary, and it was easier to measure the wavelength due to the synchronization between the excitation of the voltage source and the output light frequency.

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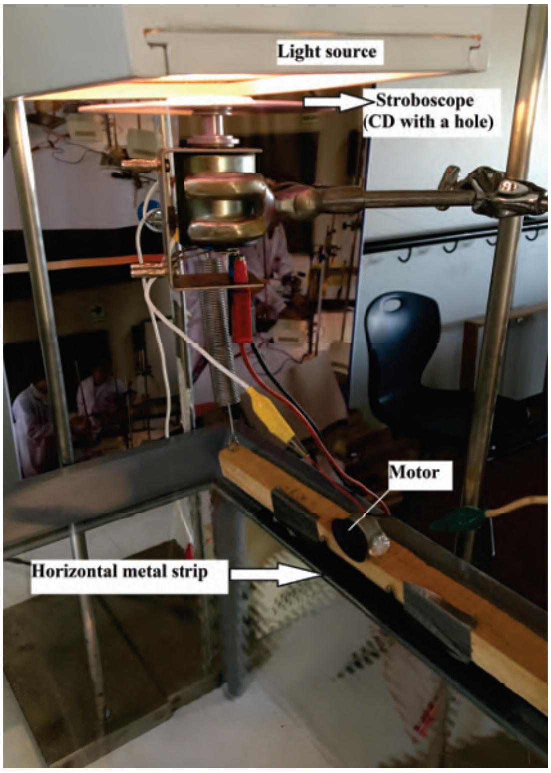

Fig. 1. Experimental setup.

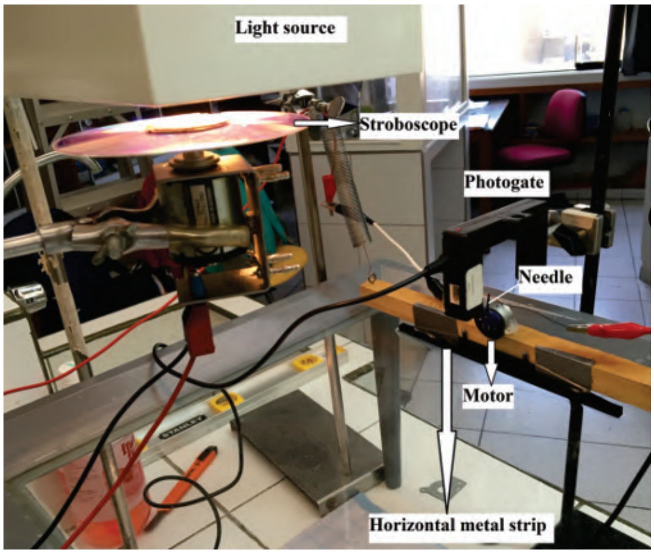

Fig. 2. Experimental setup adapted for the indirect measurement of the oscillation frequency wave.

Due to the lack of a frequency generator in the laboratory, we employed other devices that were available to obtain indirectly, the wave oscillation frequency. We decided to use a photogate (PG) with Vernier Logger Pro software.[1]. The PG works by projecting an infrared beam from one arm of the sensor to the other arm. When the beam is blocked, the sensor stops sending a signal, which illuminates a LED on the top of the gate as well as triggering Logger Pro to display a blocked message in the data collection area (these two instruments are often used for classical mechanics experiments in teaching laboratories of physics). We also used a dark, narrow and long object (similar to a needle) attached to the electric motor to cut the infrared beam of the PG at the end of a complete spin.

Next, to calibrate the voltage source with the oscillation frequency of the source, we first fixed the voltage value. After that, we recorded the number of times that the needle attached to the engine interrupted the PG in a span of 15 seconds. Finally, we divided 15 seconds into the number of oscillations done in that interval of time, which is exactly the wave period (T) for that voltage. Afterward, we repeated the procedure for different voltages values. The frequency of the wave was calculated by the reciprocal of the period (*c.f.,* Figure 2).

In the end, having measured the wavelength (λ) and the period (T) for different values of voltages, we can obtain the value of the velocity (v) of the wave propagation for a given elastic medium using Equation 1,

$$\lambda = v \times T \tag{1}$$

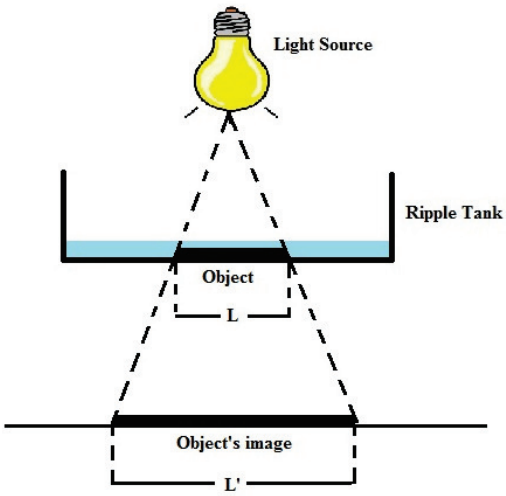

Fig. 3. Scheme for calculating the amplification factor.

To know the actual value of the measured wavelength, amplification factor (β) must be taken into account (*c.f.,* Figure 3). Hence, an object whose edges are well defined is placed into the ripple tank which is fully illuminated, then the object length, its real dimension (L) is measured; after that, the projected size (L') is gauged. Finally, the β value is obtained by calculating the ratio shown in Equation 2.

$$\beta = \frac{L'}{L} \tag{2}$$

[1]http://www.vernier.com/products/software/lp/

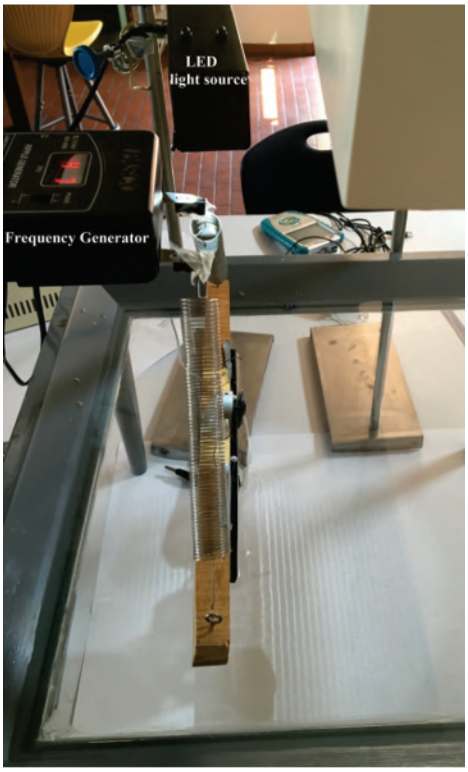

Fig. 4. Experimental setup used for the validation of the obtained results.

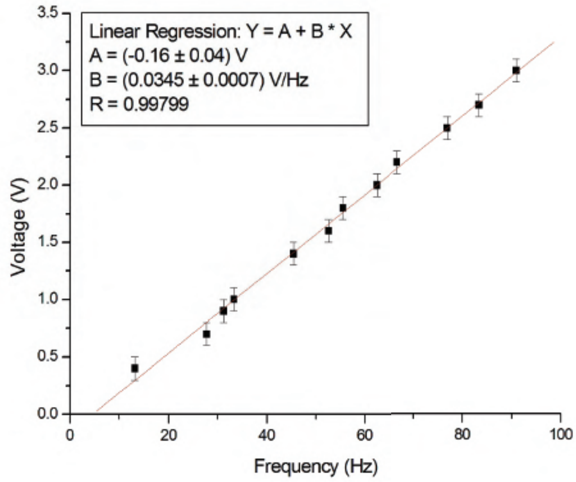

Fig. 5. Calibration curve between the voltage source and the oscillation frequency.

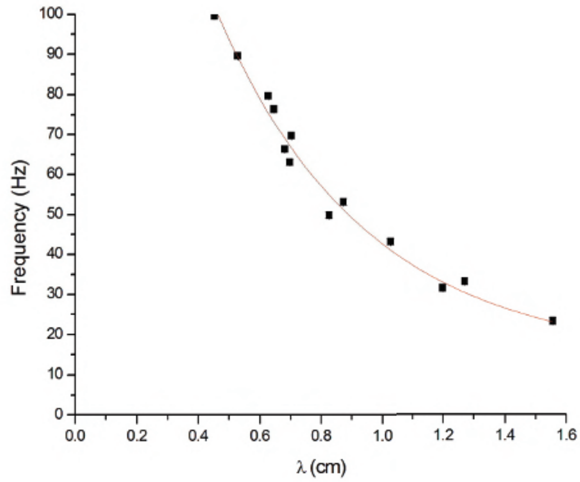

Fig. 6. The curve of the frequency and the wavelength obtained in a ripple tank with a layer of water inside.

As all the measured wavelengths were $\lambda < 1.7\ cm$, ripples were considered capillary waves and the influence of gravity was not taken into account. [3], [4], [5], [6].

The experiment was repeated for three different liquids: water, alcohol, and acetone to verify the dependence of the propagation speed and elastic medium.

To validate the results obtained with the alternative set up for estimating the frequency values in a ripple tank; the voltage source, the PG and the motor with the needle attached to it were replaced by a commercial integrated strobe/ripple generator (*c.f.,* Figure 4).

The results, as well as the validation, are detailed in the next section.

III. Results

The calibration curve (*c.f.,* Figure 5) between the voltage source and the frequency of the motor is a linear relationship, and its corresponding equation was used to obtain the values of the respective oscillation periods, calculated through the inverse of the frequency for a given voltage value.

The three studied means (*i.e.,* water, alcohol, and acetone) showed that the frequency and the wavelength are inversely proportional magnitudes. For instance, Figure 6 corresponds to the plot for the water medium, where the speed is constant. In this case, we could confirm that the studied media had not dispersion.

The speed of mechanical waves depends on the elastic and inertial properties of the medium. In Figure 7, the linear relationship between the wavelength and the period (Equation 1) obtained from the calibration curve (*c.f.,* Figure 5) is shown for a water ripple tank.

The slope of the line of Figure 7 represents the propagation velocity of the mechanical wave in that media.

The same experimental procedure was carried out using two different elastic media: alcohol and acetone.

In Table I, we summarized the results obtained for the speed

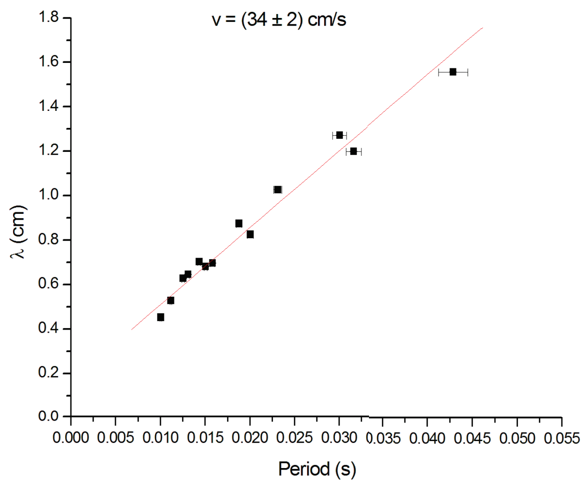

Fig. 7. The mathematical relationship between the speed (v) of a wave, its wavelength (λ) and its period (T) for a water ripple tank using the setup presented in Figure 2.

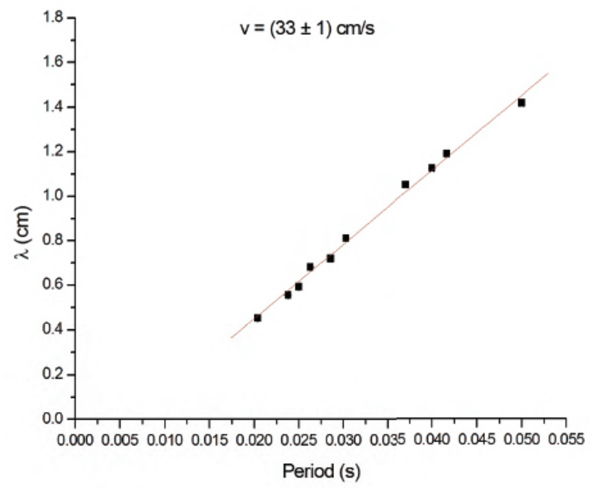

Fig. 8. Waves propagation velocity in a commercial water ripple tank.

of the wave depending on the media using the device of Figure 2.

Medium	Wave's speed (cm/s)
Water	34 ± 2
Alcohol	39 ± 1
Acetone	44 ± 2

TABLE I
MECHANICAL WAVE PROPAGATION VELOCITY IN DIFFERENT MEDIA.

Figure 8 shows the relationship between the wavelength and the oscillation period of a mechanical wave in water by using the commercial experimental device of Figure 4 to validate the previously results obtained.

If we compare the values of the wave propagation velocity in water obtained using first, the alternative experimental device proposed (Figure 2) and later on, a commercial frequency generator (Figure 4), we can observe that both results overlap, considering the experimental uncertainties.

Therefore, the alternative device used in this work to estimate the wave oscillation frequency, and hence the propagation velocity of that wave in a particular media, showed very encouraging and reliable results as well as being a cheaper variant that could be used.

IV. CONCLUSIONS

In introductory physics courses, the ripple tank setup is often introduced to show some qualitative experiences [2]. In this work, we proposed a reliable and accurate alternative experimental device to be used in a ripple tank when laboratory resources are limited, specifically when there is not an available frequency generator.

The obtained results of the aforementioned device for indirect measurement of the wave oscillation frequency encourage the use of it for teaching.

We also verified, as we expected, the direct proportionality relationship between the wavelength and the period of a wave for different elastic means.

Finally, we can conclude that the wave propagation velocity is inversely proportional to the density of a liquid (*cf.* Table I); the highest value of propagation velocity was obtained for the acetone, then for the alcohol and finally for the water.

For future works, we are interested in using the new inexpensive experimental device proposed in this article by adding another replication of it to analyze and study interference phenomena as well as non-linear effects.

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