v. 3, n. 33, 2023

Journal of
Engineering
Research

STUDY OF WAVE PHENOMENA THROUGH EXPERIMENTAL VERIFICATION

Maria Eduarda Silva Castro
Patrocínio – Minas Gerais
https://lattes.cnpq.br/9966139927603350

Halyne Silva Borges
Instituto Federal do Triângulo Mineiro – Campus Patrocínio
Patrocínio – Minas Gerais
https://lattes.cnpq.br/2763504129786617

Abstract: This work consists of the experimental investigation of wave phenomena using devices developed with technologies that allow greater depth in the concepts studied in physics classes. The activities carried out range from setting up experiments, collecting and analyzing data to preparing teaching materials, as well as preparing practical guides. The phenomena studied are investigated through three experiments: the determination of physical quantities of simple harmonic motion in a mass-spring system, the measurement of the speed of sound using a multichronometer with data processing, and the analysis of the refraction of a two-dimensional wave on a liquid surface.

As a teaching tool, these experiments were applied to 2nd year high school students at IFTM Campus Patrocínio, with the aim of developing their practical skills in the laboratory. For execution, a set of diverse experiments and high quality and precision equipment were used. These devices were developed by the company CIDEPE – Industrial Center for Teaching and Research Equipment. Along with the equipment, CIDEPE provides experimental activity books containing the user manual for each of them, used during each experiment. The analysis and study of the data obtained in each experiment allows us to explore and relate the physical concepts studied in the wave area, as well as analyzing the impact of instrumentation on physics teaching.

Keywords: Experiments; wave; physical.

INTRODUCTION

The experimental method can be defined as the study of an artificially provoked phenomenon with the purpose of verifying or eliminating a hypothesis (SANTOS, PARRA FILHO, 2017). In this sense, experimentation is an essential stage in the production of scientific knowledge, especially in the field of physics.

Furthermore, experimental practices allow the student to act as a protagonist in the learning process (SCHWANKE, 2008). This is due to the fact that the reformulation of the learning model, through the implementation of practical activities as a complementary element to the traditional teaching methodology, awakens students' curiosity about science and contributes to the construction of scientific thinking, since they are in contact with the scientific method and working to solve problems with data provided by reality.

In this context, this article seeks to publish the results of three physics experiments that address wave phenomena, namely: determination of physical quantities (period, frequency and speed) of simple harmonic movement in a mass and helical spring system; measurement of the speed of sound using a multichronometer with data processing and scrolling; and analysis of the refraction of a two-dimensional wave on a liquid surface. Furthermore, the contribution of these experimental practices to the learning of students in the 2nd year of high school at the Instituto Federal do Triângulo Mineiro – Campus Patrocínio was analyzed, since wave content is included in the physics curricular unit of this series.

METHODOLOGY

The execution took place through bibliographical analysis of physics textbooks that cover the concepts involved and user manuals contained in the equipment, which were provided by the Industrial Center for Teaching and Research Equipment (CIDEPE). This made it possible to assemble each piece of equipment to carry out measurements, analyze data, make observations and write reports.

The experiments set up and analyzed were: 1) determination of physical quantities (period, frequency and speed) of simple harmonic movement in a mass and helical spring system; 2) measurement of the speed of sound using a multichronometer with data processing and scrolling and 3) analysis of the refraction of a two-dimensional wave on a liquid surface. In each of them, previously studied theoretical concepts were related to equations to obtain physical quantities such as the period and frequency of the oscillation (experiment 1), sound source intensity and wave speed (experiment 2) and refractive index (experiment 3). Data collection for experiment 1, as well as the variation in body position within the analyzed range, was carried out using the "Cidepe Lab V6" software, designed by the company granting the equipment. In experiment 2, the sound waves were transmitted via Bluetooth to the "Cidepe Multi_Cronometro" application, which determined the speed of the sound.

Finally, the experiments were implemented in practical activities for second-year high school students and an analysis of their contributions to learning was carried out through the application of forms for students, which provided quantitative and qualitative information.

RESULTS

EXPERIMENT 1: SIMPLE HARMONIC MOTION

Objective: determination of physical quantities (period, frequency and speed) of simple harmonic movement in a mass and helical spring system. This experiment is set up using the items arranged as shown in the image below:

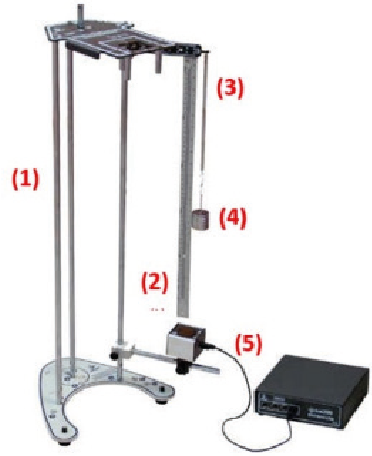

Figure 1: Experiment set 1 (MHS) - Elements contained in the set: (1) Support set with tripod, rod and screen; (2) Metal ruler 0 to 500 mm; (3) Spring; (4) Attachable cylindrical mass; (5) Ultrasonic position sensor. (Source: Cidepe Digital studios)

Initially, the mass of the coupled body is calculated using a dynamometer or scale. From this, the elastic constant is determined (k) of the spring (the force that is necessary to cause it to deform) by the formula $k = \frac{P}{\Delta x}$, , where (P) is the weight force (found by multiplying mass by gravity) and (Δx) the variation in the length of the spring (given by the difference between the initial and final length, after deformation).

By coupling a certain mass to the spring, the system is set to oscillate with a small amplitude, stretching the spring by 50mm. The oscillations are then recognized by the sensor and interpreted with the help of the "Cidepe Lab V6" software. Using the ultrasonic sensor, the software provides some tools that enable a complete description of the movement of the oscillating mass. During the experiment, it is possible to analyze the movement of the body at a certain interval using the "oscilloscope" tool, which provides its vertical displacement as a function of time. Furthermore, with the appropriate configuration of the program executed during the oscillation, the software stores the displacement of the oscillating block as a function of time in a table, allowing such quantities to be represented through graphs.

Using 4 configurations, that is, varying the masses (*m*) and springs with different elastic constants (k), a graph is obtained with the displacement of the position of the oscillating system (y) as a function of time (t). Below, in figure 2, the graphs of the systems with four different configurations are arranged (a) m= 0.25kg and k= 16N/*m*; (b) *m*= 0.25kg and k= 37N/m; (c) *m*= 0.1kg and k= 3N/*m*; (d) *m*= 0.05kg and k= 1.5N/m.

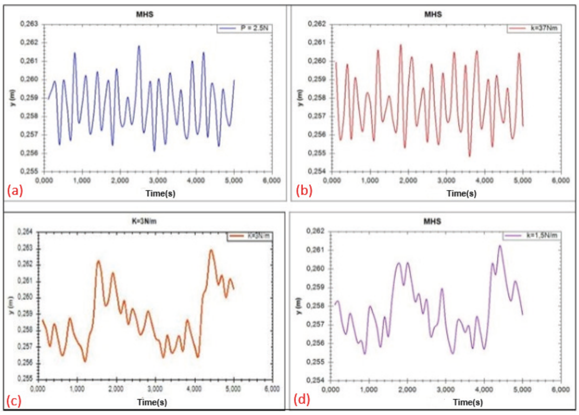

Figure 2: Vertical displacement of the oscillating mass as a function of time considering different values of mass (m) and elastic spring constant (a) m= 0.25kg and k= 16N/m; (b) m= 0.25kg and k= 37N/m; (c) m= 0.1kg and k= 3N/m; (d) m= 0.05kg and k= 1.5N/m. (Source: Personal archive)

The table below presents an analysis of the movement of each oscillating system by determining the angular velocity (ω), period (T) and frequency (f) of the oscillation.

Execution	**m (kg)**	**K (N/m)**	**T (s)**	**f (Hz)**	**ω (rad/s)**
a	0,25	16	0,78539	1,27324	8
b	0,25	37	0,51629	1,93691	12,17
c	0,1	3	1,14657	0,87217	5,48
d	0,05	1,5	1,14657	0,87217	5,48

Table 1: Physical quantities referring to the four mass-spring system configurations contained in Figure 2.

The period (T), measured in seconds, is the time required for the body to perform a complete oscillation. A large part of the practical uses of the MHS is related to knowledge of its period, since it is possible to determine other quantities based on it. The period of oscillation of the mass-spring system is given by the equation: $T = 2\pi\sqrt{\frac{m}{k}}$.

The frequency (f) determines the number of oscillations that the body makes every second, inversely to the period. This quantity is determined from the equation: $f = \frac{1}{T}$. The angular frequency (ω) corresponds to the speed at which the phase angle is covered, which is the position of the oscillating body. The angular frequency can be found through two equations, namely: $\omega=\frac{2\pi}{T}$, e $\omega=\sqrt{\frac{m}{k}}$.

From collecting data from each of the four tests, shown in table 1, some aspects could be observed. Initially, when comparing tests 2(a) and 2(b), it is observed that the same amounts of mass (m) were used, only varying the elastic constant (k) of the springs. In these results we can see the higher the m/k ratio, the longer the oscillation period and consequently the lower the frequency. Analyzing tests 2(c) and 2(d), the masses and elastic constants were changed proportionally, that is, the m/k ratio was kept constant, thus the period and frequency of oscillation remained the same. Furthermore, when observing the graphs, a certain similarity can be seen between systems 2(a) and 2(b), which present an oscillation pattern containing the most constant oscillation amplitude, when compared with figures 2(c) and 2(d). This is due to the fact that greater elastic constants make it possible to observe a more stable oscillatory pattern, suffering less influence from external factors, such as the effect of air resistance.

EXPERIMENT 2: SPEED OF SOUND

Objective: determine the speed of sound using a multichronometer with data processing and rolling. This experiment is set up with the presence of the following items arranged according to the diagram shown in Figure 3:

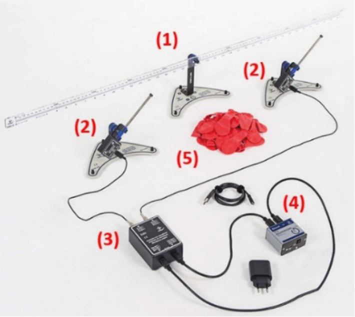

Figure 3: Setting up experiment 2 (sound speed) - Elements contained in the set: (1) Transparent ruler 0 to 1000 mm; (2) Acoustic sensors; (3) Coupler for microphones and cables; (4) Bluetooth Multichronometer; (5) Balloons. (Source: Cidepe Digital studios)

As it was shown in the diagram above (Figure 3), the sound wave emitted by the balloon burst and propagated in the air is captured by the acoustic sensors (element 2) and transmitted by the multichronometer via Bluetooth to the "Cidepe Multi_Cronometro" application. The mobile application has several functions, including "F9 Sound Speed", in which it was necessary to provide the distance between the microphones. Upon receiving data on the sound arrival time interval at each sensor, the application calculates the speed using the equation , where (v) is speed, (d) distance and (t) time:

Balloon	**d (m)**	**t (s)**	**V (m/s)**
1	0,2	0,0005769	346,68
2	0,4	0,0011594	345,00
3	0,6	0,0017454	343,76
4	0,8	0,0023634	338,50
5	1,0	0,0028914	345,85

Table 2: Physical quantities measured and calculated from experiment 2.

It is known that sound is a mechanical wave, therefore, its propagation is conditioned by the existence of a material medium, be it solid, liquid or gaseous. The energy of the sound source is transported from one point to another through the vibration of atoms around an equilibrium point, without the presence of displacement along with the wave.

There are a variety of aspects that can influence the speed of sound propagation, as well as the type of medium. In this experiment, the propagation medium was the air itself and, under constant pressure, the higher the temperature, the lower its density, causing the wave to propagate faster. When the sound propagation medium is air, and the ambient temperature is around 25 °C, the speed of sound is approximately 344 m/s. In this case, the average speed of the five tests is 343.96 m/s.

EXPERIMENT 3: REFRACTION OF A TWO-DIMENSIONAL WAVE ON A LIQUID SURFACE

Objective: analysis of the refraction phenomenon of a two-dimensional wave on a liquid surface. This way, the aim was to verify that a wave, when passing from one depth to another, refracts itself in accordance with the Laws of Refraction: 1st – The incident ray, the refracted ray and the normal to the mirror, at the point of incidence, are in the same plane; 2nd – The sines of the angles, incident (θ_A) and refracted (θ_B), are directly proportional to the wave speeds in the respective media, described by Snell Descartes' Law ($n_A.sen\theta_A = n_B.sen\theta_B$) and recognize that refraction is not always accompanied by a deviation in the wave trajectory – if the trajectory of the incident ray is perpendicular to the surface separating the media – but always generates variation in propagation speed. Furthermore, in this experiment it is possible to determine the relative refractive index of the liquid

Journal of Engineering Research ISSN 2764-1317 DOI 10.22533/at.ed.3173332325093

medium due to the variation in depth.

This experiment is carried out using the following items arranged in Figure 4.

Figure 4: Setting up experiment 3 (refraction of a two-dimensional wave) - Set elements: (1) Wave tank; (2) Cold light illuminator and stroboflash; (3) Flat generative tip; (4) Shock generator; (5) Support set with tripod and rod; (6) Glass plate. (Source: Cidepe Digital studios)

In this arrangement, the wave tank is filled with water and the glass plate is immersed in the liquid. Then, the shock generator causes waves in the water and it is possible to observe the phenomenon of refraction of a two-dimensional wave which occurs, in this case, on the liquid surface, when the wave passes from one propagation medium to another, that is, it passes from a region of greater depth to another region of shallower depth, the one occupied by the glass plate being the shallowest.

In this phenomenon, the frequency of the wave does not change, since it depends only on the source that generates the waves. However, the speed and wavelength can change. This can be represented through the fundamental wave equation: $v=\lambda .f$, where (v) represents the speed, (λ) the wavelength and (*f*) the frequency. Since the frequency remains the same, the speed and wavelength increase or decrease in a directly proportional manner.

The refractive index (n) is a relationship between the speed of light in a vacuum (c) and the speed of light in a given medium (v), described through the equation: $n = \frac{c}{v}$. The relative refractive index is given by the ratio between the refractive indices of two different media(n_A/n_B). To calculate the relative refractive index in the experiment, it was first considered that the incident wavefront is the one that propagates in the deepest region (outside the region of the glass plate), therefore half A, and the refracted wavefront is that which propagates in the shallowest region (on the glass), therefore medium B. Using a straight line as a reference, the angle between the incident wave from medium A and the refracted wave from medium B was determined, called θ_A e θ_B .

Found yourself $\theta_A = 56°$ and $\theta_B = 50°$, however, the values have been corrected due to the projected image correction factor (F_A = 0,55): $\theta_A F_A = 30{,}08°$ and $\theta_B F_A$ 27,5°. Thus, the sine of the two angles was calculated: *sen* $\theta_A = 0{,}501$ and *sen* $\theta_B = 0{,}461$. From this, Snell's Law was used, which associates the different refractive indices of the media with their respective angles of incidence and refraction: $\frac{n_A}{n_B} = \frac{sen\,\theta_B}{sen\,\theta_A}$. Finally, the relative refractive index was obtained:

$$\frac{n_A}{n_B} = \frac{0{,}461}{0{,}501} \rightarrow \frac{n_A}{n_B} = 0{,}912.$$

CONTRIBUTIONS TO PEDAGOGICAL PRACTICE

Practical activities with students were made possible by the production of activity scripts, which demonstrate the step-by-step execution of experiments in a more objective and clear way compared to user manuals. Furthermore, they explain the phenomena to be analyzed, as well as which quantities are quantified through the application of the formulas.

The improvement in understanding of physics was noticeable through the results of a survey that sought to evaluate everything from students' interest to improving their performance in the subject. The calculation in question was carried out using a form in which students reported the impact of the experiment on their learning, as shown in figure 5.

Figure 5: Graph of answers provided by students on the form.

The survey was answered by 50 second-year high school students. By analyzing the graph that quantifies the degree of engagement based on five aspects of experimental practices. It is observed that the stimulation of scientific curiosity is the factor best evaluated by students, as predicted. The learning provided by carrying out the experiments also obtained a satisfactory overall evaluation. Furthermore, evaluations corresponding to the quality of execution related to both organization and active participation, in addition to affinity with the laboratory environment, and together with comments, allow us to identify possible ways to improve practice together.

CONCLUSIONS

In short, the main contributions of the research are related to the applications of experimental practice, which provided active participation in the stages of the scientific method, making it possible to determine results predicted by theoretical knowledge. In this sense, the process of producing scientific knowledge is understood. The investigation of wave phenomena through devices capable of collecting data with greater precision is notable for improving the learning process

REFERENCES

ALVARENGA, B. A.; MÁXIMO, A. R. **Física: Contexto & Aplicações: ensino médio.** 2. ed. São Paulo: Editora Scipione, 2016. Vol. 2.

CIDEPE. **CIDEPE – Centro industrial de Equipamentos de Ensino e Pesquisa, 2022. Cidepe Digital.** Disponível em: https://www.cidepe.digital.com.br. Acesso em: 02 de setembro de 2023.

RAMALHO, F.; NICOLAU, G. F.; TOLEDO, P. A. **Os Fundamentos da Física 2: Termologia, Óptica e Ondas.** 9. ed. São Paulo: Editora Moderna, 2014. Vol. 2.

SANTOS, João Almeida; PARRA FILHO, Domingos. **Metodologia Científica.** 2. ed. São Paulo: Cengage Learning. 2017.

SCHWANKE, C., CARUSO F., BIANCONI M. L. **Instrumentação para o ensino de Ciência.** Rio de Janeiro: Fundação CECIERJ, vol. Único, 278p, 2008.