Waves: Common Representations and Related Teaching/Learning Sequences

Claudio Fazio, Rosa Maria Sperandeo-Mineo, Giovanni Tarantino
UP_PERG (University of Palermo_Physics Education Research Group)
Dipartimento di Fisica e Tecnologie Relative, Università di Palermo, Italia
tarantino@difter.unipa.it

Abstract

The understanding of physics wave concepts is considered a crucial requirement for making sense of many important physics topics as optics, quantum mechanics and electro-magnetic radiations. However, in the majority of high school curricula, wave physics actually plays a secondary role especially with respect to other content fields as mechanics and thermodynamics. In fact, many research studies have shown that students have fundamental difficulties dealing with the basic concepts of wave physics. These difficulties mainly involve the concepts of propagation, superposition and mathematical description of waves.

Here, we describe the first part of a Teaching/Learning (T/L) sequence aimed to overcome these well-known difficulties. The starting point is based on the common models used by students to describe wave phenomena. The sequence involves the analysis of propagation of elastic waves by using simple RTL experiments and simulation environments. The spectral analysis of signal is also used in order to discuss the properties of sound waves generated by different acoustic sources and music instruments.

Introduction

In last years many research studies have pointed out relevant student difficulties in understanding the physics of mechanical waves [1] Moreover, it has been reported that these difficulties deal with some fundamental concepts as the role of the medium in wave propagation, the superposition principle and the mathematical description of waves involving the use of functions of two variables [1, 2]. Similar results we have found in some investigations carried out with a 24 trainee-teacher (TT) group attending the pre-service course for teacher preparation [3]. In the same context, we have also experimented a teaching/learning (T/L) sequence based on using simple RTL experiments and interactive simulation environments aimed to show the effect of medium properties on the propagation speed of a wave pulse.

This paper reports some experiments aimed to a better understanding of the critical concept: "Wave propagation is a medium's response to a disturbance, and the propagation characteristics depend only on the medium and not on the nature of the disturbance". In particular we will concentrate on the characteristic property "velocity of propagation".

1 The experiments

In order to make TTs aware that speed of propagation of elastic waves only depends on the properties of media, we have performed the measure of the speed of propagation of a sound wave in various media. We analyse the propagation of the same kind of pulse in different media.

1.1 Sound speed in air

Figure 1 shows how the experiment is performed. A couple of microphones, placed at a fixed distance, L, are connected to a computer data logger and are used to measure the time it takes a sharp sound to travel the distance between them. The distance between the microphones divided by the time delay between the start of each signal detected by the microphones gives the speed it takes to sound to go from one microphone to the other one.

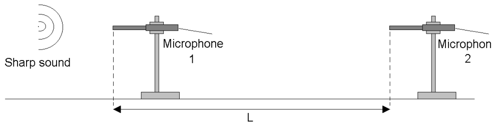

Figure 1

1.2 Sound speed in solids

If we produce a shock wave at one end of a metallic rod by the means of an hammer stroke it is possible to see a pendulum bob, initially in contact with the other rod's end, displacing as the perturbation arrives. This demonstration can be used to measure the speed of acoustic waves in metals by making an electric circuit with rod, metallic pendulum bob, thread and hammer, as sketched in figure 2.

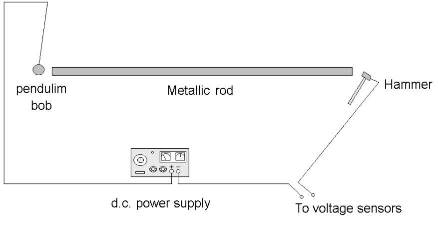

Figure 2. Sketch of the experimental apparatus used to measure the velocity of shock waves in metals.

The electric circuit is closed when both the hammer head and the pendulum bob are in contact with the metallic rod. The idea is to hit the metallic bar with the hammer head [15] when the pendulum bob is at rest, in contact with the bar; the action closes the circuit and a d.c. voltage, due to an external power supply, is detected by voltage sensors connected to a computer data logger until the shock wave arrives to the other bar's end and makes the bob displace, actually opening the electric circuit.

The detected signal only lasts until the circuit is closed, i.e. from the moment the wave is generated to the moment it arrives to the other end of the bar, so the actual time it takes to the wave to go from one end to the other of the rod is easily measured by analysing the duration of voltage peak detected by the sensor. By measuring this time and the rod length, the speed of the acoustic wave in the rod is obtained.

2. EXPERIMENTAL RESULTS

Figure 3 reports a typical signal detected with the experimental apparatus described in paragraph 1.1.

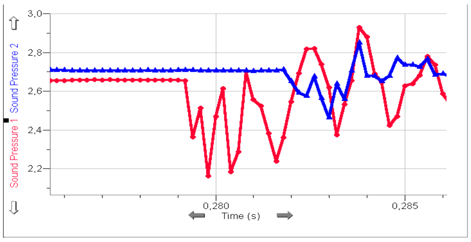

Figure 3. Signals detected by two microphones placed 2 m apart when a sharp sound gets to the nearest one and then to the other.

Measurements where performed several times with microphones placed at different relative distances; the mean value of the sound speed in air obtained with this method at a room temperature of 22 °C is (346 ± 3) m/s.

Measurements described in paragraph 1.2 were performed using aluminium and brass rods 3 meters long. Figure 4 reports a typical signal detected by the data logger.

Figure 4. Typical signal detected by the voltage sensors.

The time needed to the shock wave to travel through the rod and make the pendulum bob displacing, actually opening the electric circuit, can be easily measured by considering the time interval corresponding to the constant part of the peak. In the particular case reported in figure 5, the value for this time is (9.0 ± 0.5) 10^{-4} s, the experimental error being calculated as a time interval between two successive data samples (here the data sampling rate is set to 20,000 samples per second). From this value and the known length of the rod the value of the acoustic waves speed in brass is easily obtained.

Measurements for the brass and the aluminium rods were repeated 10 times and means were calculated, giving the values for the acoustic waves speed in the two metals reported in Table I.

Table I

Mean values of the acoustic wave speed in brass and aluminium rods. Means refers to 10 measurements; errors are reported as the standard deviation of the mean for each set of data

Metal	Speed Value (m/s)
Brass	3400 ± 30
Aluminium	5010 ± 50

Conclusions

The reported experiments show that for the same kind of perturbation a relevant propagation characteristic "the speed of propagation is strongly depending on the medium.

References

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[15] In order to make the hammer head not bouncing back before the pulse reaches the other end of the rod, actually opening the circuit, the hammer mass must be sufficiently high [4]. We used a 0,5 Kg hammer head and verified it didn't appreciably bounce back during the experiment.