Video Analysis of Pulse and Standing Waves in an Elastic Spring

Daniel Rodrigues Ventura[1,3], Paulo Simeão de Carvalho[2,3], Marco Adriano Dias[3,4,5]
[1] COLUNI, Federal University of Viçosa, MG, Brazil; [2] DFA, UEC, FCUP, University of Porto, Portugal;
[3] IFIMUP-IN, University of Porto, Portugal;[4] IFRJ - Rio de Janeiro - RJ, Brazil.[5] Oswaldo Institution Cruz/EBS/FIOCRUZ-Brazil
dventura13.drv@gmail.com

Introduction

The word "wave" is part of the daily language of every student. However, the physical understanding of the concept demands high abstractive thought.
In teaching practice, we need to develop strategies and use tools to help the students in the learning process.

We present an interactive strategy for teaching pulse reflection in springs using **image modelling**. This technique involves the use of digital videos, enabling the creation of stroboscopic images for a conceptual description of a particular problem, and a subsequent video analysis to conduct a quantitative study of the phenomena.

An elastic spring can be very useful for the observation and analysis of the harm onics in standing waves, and for teaching the concepts of pulse reflection and wave propagation speed.

We show that very affordable resources such as:

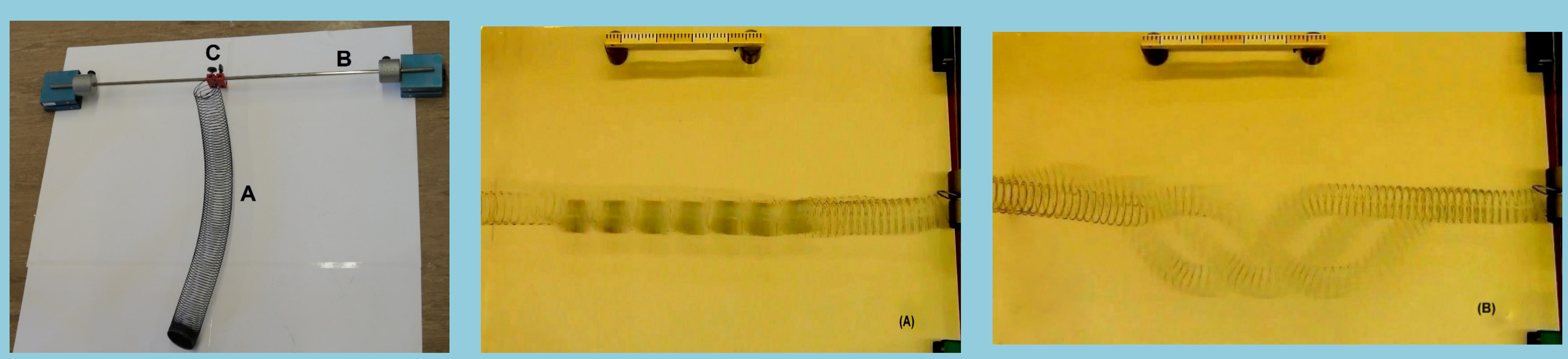
- an elastic spring
- the freeware software Tracker for video analysis

can be very useful for the teaching of mechanical waves propagation, as well as the analysis of harmonics in standing waves.

Experimental

To study the mechanical waves, a black painted metal spring was fixed to a platform. The spring was illuminated by white light projectors to enable a good contrast of the spring against a white background.

Video images were captured with a digital photo camera Canon EOS 5D Mark III with HD 1280 x 720 MP resolution at 60 frames per second, and a CMOS Full Frame - 36 x 24 mm^2 sensor.

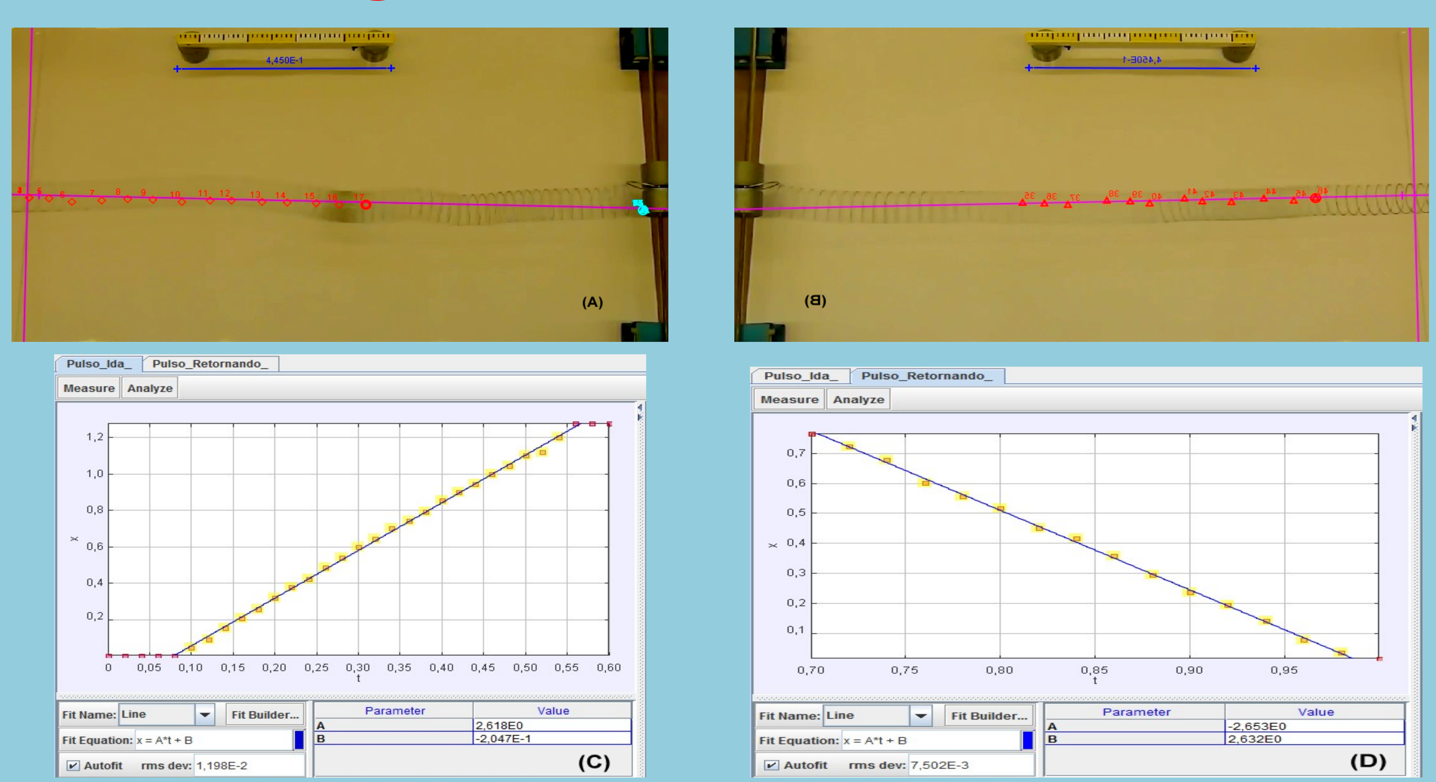


Pulse Reflection

The study relies on the behaviour of longitudinal and transverse pulses in a slinky spring produced before and after reflection, in a mobile and fixed ends.

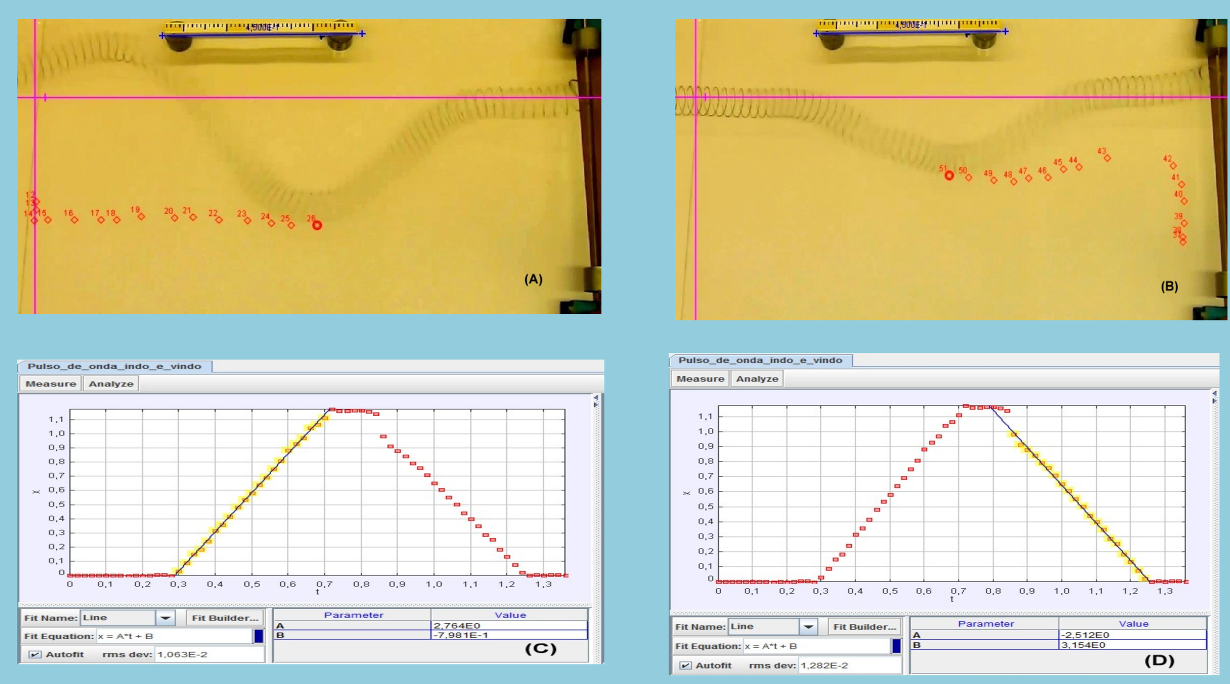
A POE methodology is suggested for educational purposes: first there is a description of the problem by the teacher from a stroboscopic image, and then (P) students make their predictions, (O) and investigate the motion of the spring with *Tracker* software and finally, (E) they try to find an explanation for the phenomenon.

Longitudinal Pulse Reflection

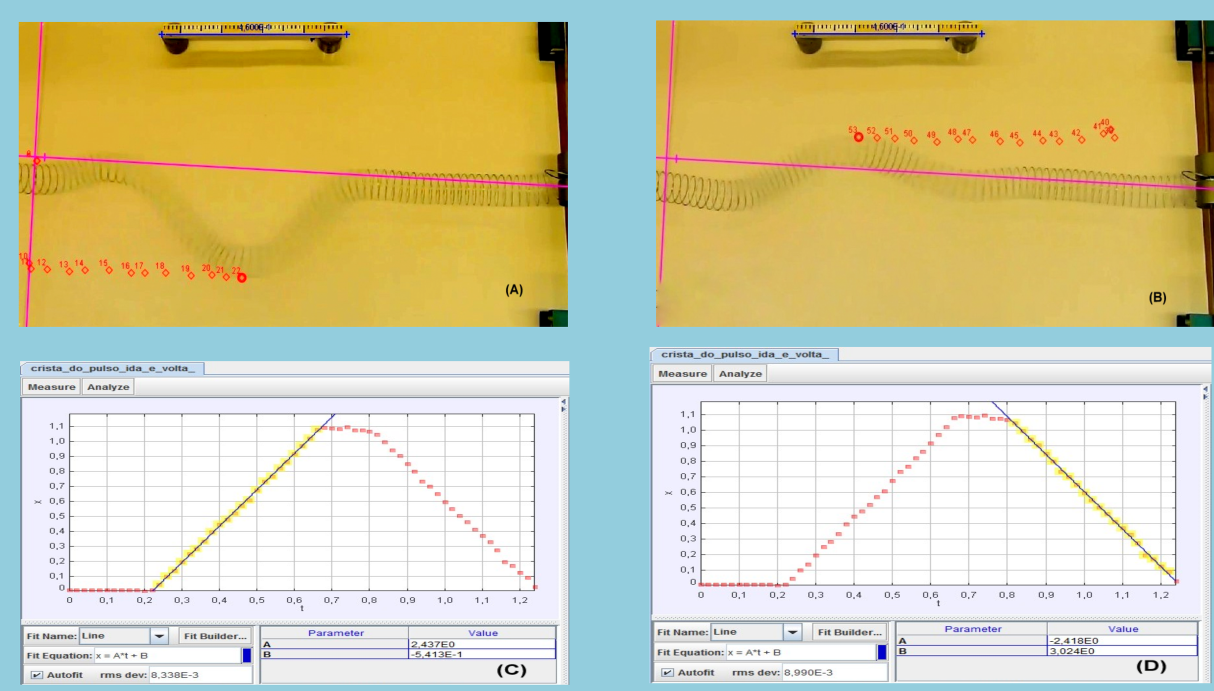


Transverse Pulse Reflection

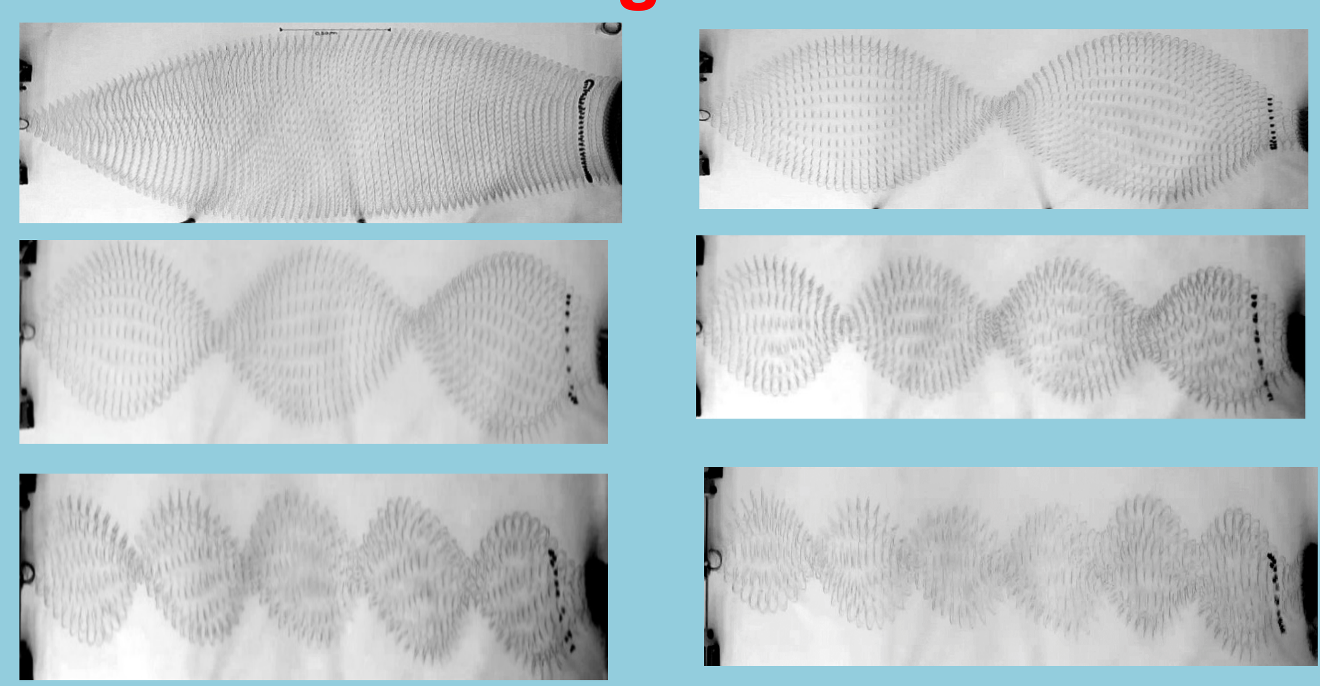
Pulse reflected in a mobile end.



Pulse reflected in a fixed end.

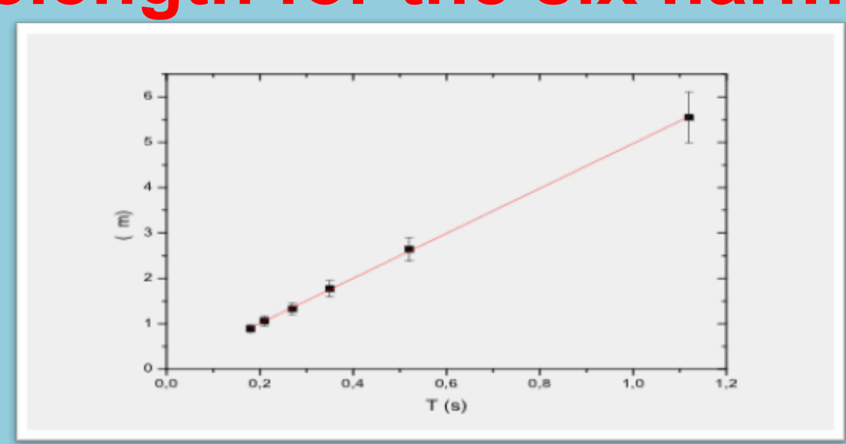


Standing waves



Stroboscopic images of the spring vibration, from the 1st (top left hand) to the 6th (bottom right hand) harmonic. The wavelength is measured making use of the calibration bar within the videos.

Wavelength for the six harmonics



The wavelength as a function of the period, for the first six harmonics obtained from video analysis.

The slope of the linear fit gives the speed of the propagation of waves in the spring. The obtained value in the example is v = 4,94 ± 0,04 m/s. This value depends severely on the elastic characteristics and/or the tension of the spring.

Conclusion

The video of this experience, available on the internet, may be also explored as an activity of curricular enrichment outside the classroom, to be later discussed and complemented at the school's laboratory.
For those teachers without resources or access to laboratory infrastructures, the video analysis enables them to explore the topic of stationary waves with low cost and affordable resources.

Acknowledgments: This work was funded by CNPq (Conselho Nacional de Pesquisa), PDE, 206324/2014-6, by Fundação para a Ciência e a Tecnologia (FCT), Project UID/NAN/50024/2013 and by CAPES (Coordenação de Aperfeiçoamento de Pessoal de Ensino Superior) (BEX 3275/15-9).