Will it still work or not? Simple experiments at extreme parameters

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Abstract

The question "Will it still work or not?" belongs to one of the basic questions of SCHOLA LUDUS for simple experiments. Sequences of experiments that differ only in a value of a chosen property of the system towards the threshold of the system functioning are used for enhancement of students understanding of the realized process and of physics understanding in general. As an example, experiments with the "thread phone" are used to approach sound propagation on a level of advanced high school students.

Introduction

Simple experiments do not mean that the understanding of physical, chemical, respectively biological processes realised during the experiment are really simple. In SCHOLA LUDUS [1] simple experiments are supposed for learning by playing. Simple experiments are those that could be easily provided and alter in at least one parameter. The learning procedure described in this contribution is based on sequences of the experiments. Successive experiments from this sequence differ in a value of the same parameter. Each experiment of the sequence starts by the same question "*Will it still work?*". Then, special attention is given to the value of the parameter at which the behaviour of the system is radically changed or the observed phenomenon disappears or the system collapses.

As a besides but very desired effect of this learning approach is a sufficiently hot atmosphere that is created in the classroom. Students become very creative in practical, and theoretical ways. They give questions related the existence of the observed phenomenon and propose new orders of successive experiments, changing step-by-step another of the system's properties, etc. And the teacher has opportunity (in dependence on the student level of understanding) to turn their minds towards physical models of undergoing physical processes including understanding the boundary conditions, unstable states and borders of the respective phases of the process [2], etc.

It is clear that, to complete the procedure in the way described above, needs a sufficiently long time, i.e. the choice of the experiment is very important. In this way experiment can be understood also as a key experiment to one of the physics themes. In this paper the *"thread phone"* simple experiment is described as an example introducing the physical theme "Sound".

1. Thread phone

The basic system configuration of the experiment consists of two vessels linked by a thread. Question arise:

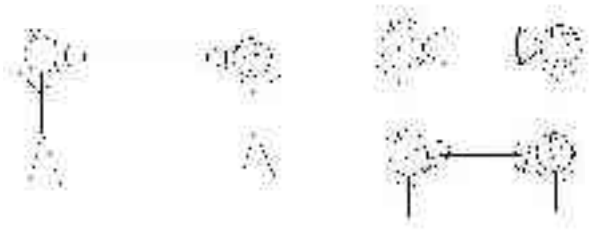

Figure 1. Thread phone.

How is it possible that this simple system is, at certain conditions, really transmitting words? What are the conditions of its functioning? Or, for students´ better motivation: *Where are the limits of its functioning? At which range of parameters is it working?* And going deeper in the matter: *What are the functions of the system ´s parts? Which of the phones is working better, the one of large vessels, or the one of small vessels? What is the function of the vessel walls, and what is the function of the vessel bottoms? Which of the thread materials is the most suitable to transmit the sound? Does the velocity of the sound influence comprehensibility of the transferred words? How is it with the sound losses? Are the vessels and the thread all what we have to take into the consideration in order to understand the functioning of this simple equipment?*

Before answering these questions we need experiments. We need to change parameters of this simple physical system, and also measure its characteristics, where it is possible. And, to learn a portion of its physics, we also need discuss simple models of the going on process. And, before all, we need hypotheses concerning the problem.

2.1 Basic hypotheses and the first experimental discoveries

Considering functions of the respective parts: The walls of vessel directs the sound. The bottom of the vessel works like a membrane. The tread plays the role of sound wave conductor. By playing during which pupils change the parameters they can discover, among others, that:

1) The thread must be tight/ stretched, but if it is changed by a metal wire, the wire is functioning even if it is shaped into spiral.
2) With certain material of the thread the sound could be heard and words recognised even across a 200 meter long thread.
3) Phones with turned vessels work too, even with a sheet of paper, cartoon, polystyrene or pure balloon membrane in a frame.
4) The functioning of the experiment depends on the way how the thread is linked to the bottom of the vessel or the sheet.

2.2 Physical reasoning and further questions

From the 1st discovery and the basic knowledge about the forces between molecules in metallic materials we can conclude that the binding forces between molecules play a significant role at sound propagation. Modelling the front of the wave by the domino effect (Fig.2a), and adding 2D elastic bindings between the molecules (Fig.2b), the propagation of sound through a stretched thread can be imaged by local changes of molecules´ density. I.e., the density in a small volume of material increases while in the neighboring volumes decreases, etc. Described changes of density concern huge number of molecules. But the macroscopic changes can be only weak due to restriction of attractive and repulsive forces between molecules, and temporal, similar as shows the front of the wave in the spring (Fig.2c). The sound is propagated in waves (Fig.2d) but it must be emphasised that the demonstration concerns only changes of the local density, (the maximum value ±1 and the minimum 0).

The 2nd, rather surprising discovery with the relatively long thread underlines the effect of the elasticity of the bindings between molecules. From the result we can conclude that only a small amount of energy is changed into thermal - chaotic vibrations of molecules. An open question is, what could be the maximum length of the thread to transmit the words? Though pupils hardly can get a unique answer, the problem can be discussed in terms of intensity losses through over the stretched thread of different lengths and the audibility threshold. Here we can get also to the problem of "sound capacity of the sound conductor" or to the question about the existence of a maximum intensity that can be transmitted by the certain "thread". This is the consequence of the thread material, its shape, volume and strength between the molecules (and the temperature and the freqency of the sound)! Also, theoretical conclusions can be improved by new, more enhanced sequence of "phone" experiments: The simple vessel on one side is substituted by a speaker located in a box that is protected from sound propagation, on the other side by a microphone in a similar box., while both speaker and microphone are connected to a (digital) oscilloscope. And the goal is, of course, to find the maximum - "extreme" value of the sound intensity transmitted from the sound source to the receiver.

According to the 3rd discovery our phone communication is possible also replacing the vessels by membranes. But nor the original rather firm bottom of the vessel, nor the bottom from a balloon membrane showed visible vibrations. The membrane function is to provide the transition of sound from air into the thread, and the frame of the membrane is important as the center of the membrane is vibrating in the rhythm of the sound wave with respect to this frame. Finally, the 4th discovery, that relates the way how the thread is joint with membranes, gives hints to consider that the basic sound vibrations in the thread are transversal, similarly as in the air (Fig.2e).

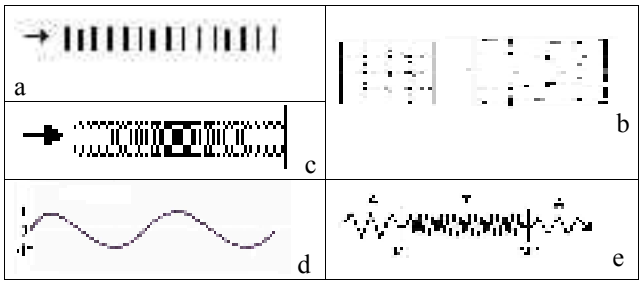

Figure 2. Demonstration models of sound propagation
a) domino
b) elastic net of molecules and group of molecules, respectively
c) spring
d) standing waves
f) transverse propagation in A-air and T-thread via M1 and M2 membranes

Conclusions

By changing successively a system characteristics in order to get to the limits of the system functioning, students´ inquiry is enlarged. They are motivated to discuss also the physical inside of the problem. And if we combine experiments at extreme parameters with several models, students knowledge becomes more complex.

References

[1] TEPLANOVA, K Computers and modelling at SCHOLA LUDUS teaching of physics. GIREP,Ostrava, 2004, pp. 120-121
[2] BIZNAROVA, V., TEPLANOVA, K. Research on students concepts using SCHOLA LUDUS tests. GIREP. Ostrava, 2004, pp. 191-192