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Playing pipes

You want to know how the organ work? You can easily check it in this experiment. It is both a colorful illustration to a lesson on acoustics and an interesting toy for the youngest. The time of preparation – about 40 minutes, the cost – about a few Euros.

1. Required materials:

To conduct experiments you will need:

- 2-meter PVC pipe with a diameter of about 2-3 cm, accessible for example in a construction market,
- colorful paper for marking pipes,
- colorful balloons,
- a saw for cutting plastic or metal,
- fine sandpaper,
- rubber bands,
- measure.

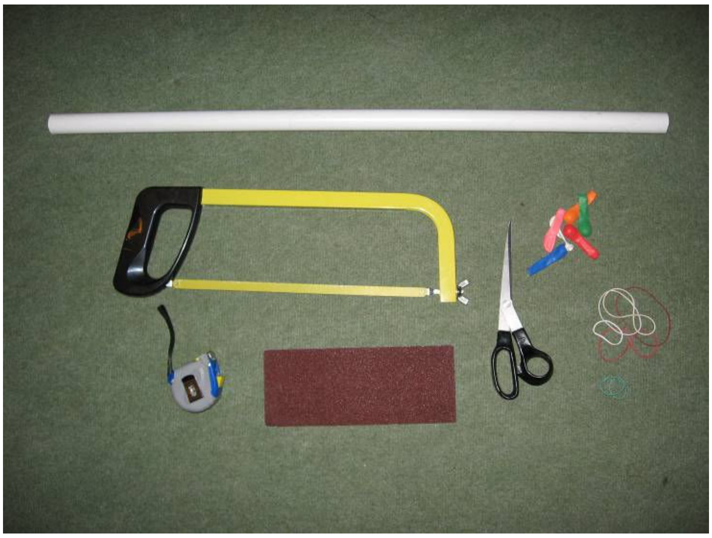

Fig. 1. Set of elements required for the experiment.

2. Realization:

To build an instrument you shall cut a long PVC pipe into several pipes of definite lengths, so that they could be used to reinforce sounds of the musical scale. Below you can see a table with pipe lengths appropriate for each sound in the scale:

Table 1. Length of pipes for subsequent sounds in the scale

sound	frequency[Hz]	pipe length [cm]	color
c^1	261,6	31,68	
d^1	293,7	28,22	
e^1	329,6	25,11	
f^1	349,6	23,70	
g^1	391,9	21,15	
a^1	440,0	18,84	
h^1	493,9	16,75	
c^2	523,3	15,84	

When you obtain pipes of a proper length, it is recommended to "polish" terminals with sandpaper and stick a paper stripe in an adequate color. At that moment instruments are ready – sounds are obtained by clapping with open hand in a pipe exit, as shown on Figure 2.

Fig. 2. Obtaining sounds from a pipe without a balloon.

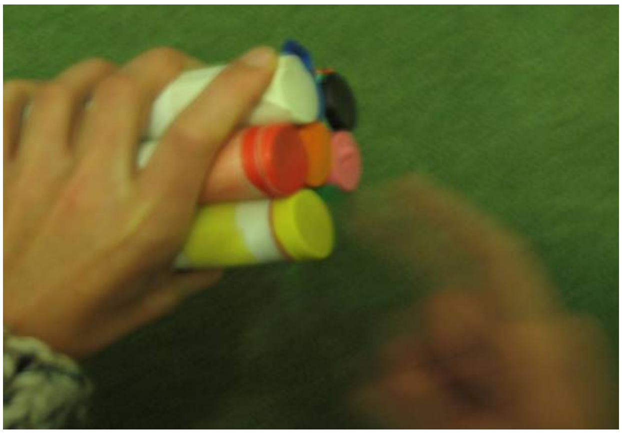

Fig. 3. Obtaining sounds from pipes with balloons.

Colorful balloons are used only for making instruments more efficient. Balloons shall be cut into small pieces, pulled over pipes and fixed with rubber bands or rubber rings cut out of a balloon mouthpiece. To obtain a sound you shall tap gently a tightened rubber with your finger, as shown on picture 3. It is recommended to use the same colors of balloons as in table 1. All pipes can be fastened together to form the organ presented on picture 4. Conducting that experiment with the whole class can be an interesting experience. Pipes with marked colors shall be distributed among students and on the board you shall place a colorful transcription of some melody. When a teacher shows successive colorful fields, students are supposed to tap in suitable pipes. In attachment you will find transcriptions of several popular melodies.

Fig. 4. Ready-made instrument.

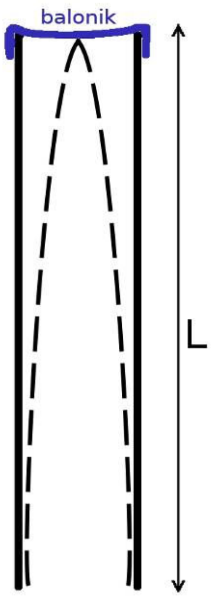

Fig. 5. Diagram of a sound wave inside a pipe.

3. Theoretical explanation

When you tap a pipe exit, some air is pushed out of it. A pressure inside the pipe is for a moment lower than atmospheric pressure around it. Afterwards, air is “sucked” from outside, which brings about high pressure inside the pipe. The process reiterates with a declining amplitude. Concentrations and rarefactions of air propagating from the opposite exit of the pipes are perceived as a sound. Such a process is the most effective (the longest duration with a high amplitude) in a resonance case, that is when the wave of air moving inside the pipe forms a standing wave as shown on picture 5. At the tapped pipe end pressure fluctuation is the smallest, which is symbolized by the wave knob on Fig. 5. In accordance with the previous description, the opposite pipe exit is marked with a wave arrow, which means that air moves at a greatest speed there and air density fluctuations are the most drastic. It can be deduced from the diagram 5 that the pipe is four times shorter than a round wave length obtained from the instrument.

In order to calculate pipe lengths you must use frequencies of sounds in the scale indicated in the table 1 as well as a formula that relates velocity of sound wave V_{sound} with its frequency f and wave length λ:
$V_{sound} = f\,\lambda$.

In calculations we assumed that V_{sound} = 331,5 m/s. Pipes are four times shorter than length of sound waves evoked by them. Therefore, the above formula allows for calculation of their length:
$L = V_{sound}/(4f)$.