A few words about the acoustic workshop

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Introduction

The acoustic workshop is a comprehensive set of experiments which we've performed at various places in the past few years. The workshop covers topics from the sources of sound, sound transmission through different environments, measurement of the speed of sound, interference of sound waves to the principles of sound recording. In this text you'll find descriptions and analysis of several of these experiments: the principle of sound reproduction using a gramophone, the principle of sound reproduction using a tape recorder, including deleting a sound record, also the description of several atypical sources of sound ("cosmic sounds") and an experiment showing our ability to locate sources of sound. In the following text we tried to describe the listed experiments in a way so that a potential interested person could easily repeat them and add them to their teaching repertoire. We present a list of the necessary tools, we describe how to carry out the experiments and add methodical notes.

Gramophone – the powerhouse of sound equipment

Just a few years back we had been introducing this experiment by saying we are going to show an obsolete way of reproducing sound recordings. Even though it is not being used anymore, we said that it is useful to get to know the principle. Today, surprisingly, we see a resurgence of gramophone recordings. Gramophones are once again being made and a lot of recent music albums come out on gramophone records.

The gramophone is not the oldest device for recording sounds. That has been the phonograph. Nowadays this device can only be seen in museums. Therefore, we begin our excursion to the history of sound recording with the gramophone.

Tools: paper roll made of a tougher kind of paper or cardboard (for example a toilet paper roll), tracing paper, a needle, paper glue, universal glue (e.g. UHU brand), scissors. Next, you'll need an old gramophone with a functioning turntable (you can also use a broken one – manually rotating it) and an old gramophone record (with quick rhythmic songs – granny's record of brass-band music or grandpa's old military marching songs are quite adequate for our purposes)

Execution: Glue a membrane of the tracing paper on the paper roll. It's good to trace the cross-section of the roll on the tracing paper and add a zigzag pattern for easier gluing. After the glue has dried up, glue a needle on the membrane as shown on the picture (pic. 1) Use the needle, not a pin.

Picture 1. A simple phono cartridge

A pin is not sharp enough and its shape is not suitable for our purposes. The needle should protrude by 5 - 10 mm over the edge of the membrane.

After the glue has dried up perfectly you have made a simple gramophone cartridge. Put the record on the gramophone turntable and turn on the rotation. Carefully place the needle on the grooves of the record. Hold the cartridge perpendicularly to the disk grooves, because the sound is recorded "sideways". A correct way to hold the cartridge is shown on picture 2. The reproduced sound may surprise you. If the membrane is tight and the needle sharp the sound is surprisingly good. You can try to turn up the volume of the record by creating a paper cone and gluing it to the cartridge.

Picture 2. Playing a gramophone record

There's one disadvantage to this type of gramophone. The needle severely damages the record which hinders its replayability.

Notes: If you're handy you can make it work even without a gramophone. You can put the record on a tip of a pencil. You'll also need an assistant to play the record. One of you will turn be turning the record whilst the other one holds the cartridge. The most important thing in this case is to find the right turning speed for the record.

Tape recorder principle

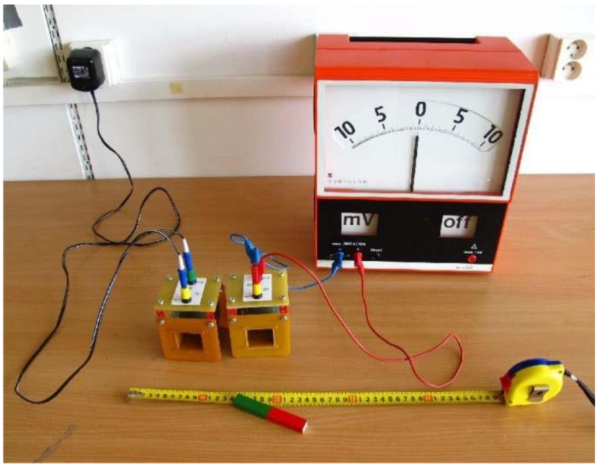
The simple gramophone cartridge from the previous experiment may not have shown a high quality of sound reproduction, nevertheless it worked. A similar experiment using a tape recorder would be too complicated. Therefore, we shall focus on a demonstration of the physical principle of recording, reproduction and deletion of a record.

Unlike the currently resurging gramophones, tape recorders are mostly unused nowadays. We will demonstrate the principle of this rarely used device. Its predecessor was a device called the telegraphone which used a thin wire as a recording medium unlike the tape in a tape recorder. Compared to the gramophone the tape recorder (and the telegraphone) had an additional property. The recording could be deleted and exchanged for a different recording.

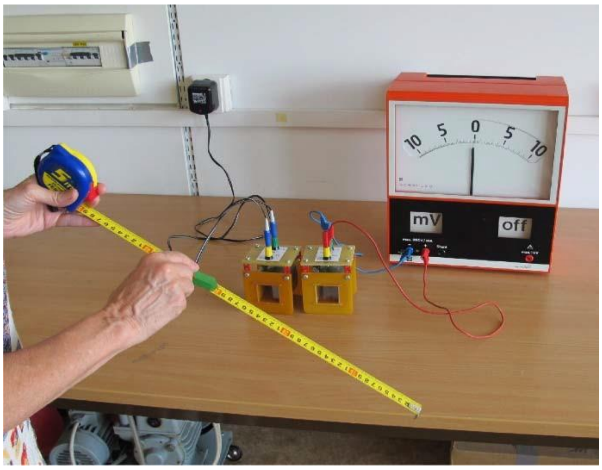
Apparatus: inductors 600 and 1200 turns from the school transformer set, a voltage source 12 V (AC), a metal tape measure, a bar magnet, a demonstration voltmeter.

Procedure: Connect the 600 turn coil to the voltmeter. This coil will serve as the playback head. Set a low range on the voltmeter (e.g. 10 mV with zero value in the middle). Connect the second coil (1200 turns) to the source of voltage (12 V). This coil will act as the erasing head in our model. Our setup can be seen on picture 3a. Pull around a meter of the tape measure and slide it into the erasing head (the coil connected to the voltage source) and pull it through and back again a few times. This way you'll get rid of any previous magnetization of the tape. Now, you are going to create the recording. Hover one pole of the bar magnet above the 10 cm mark on the tape measure, do the same with the other pole of the magnet above the 30 cm mark and then use the first pole on the 50 cm mark and continue like that (picture 3). Pull this magnetized tape through the other coil connected to the voltmeter.

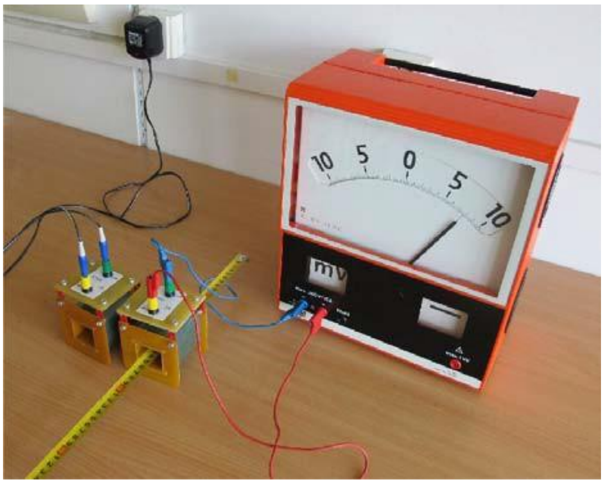
Observe the deviation of the hand of the voltmeter during the passing of the magnetized marks (picture 3c). This way you are demonstrating how a magnetized tape can record a signal and "play" it. A magnetic tape or a metal wire of a telegraphone is replaced by a tape measure in this experiment. If you'd like to delete the recording pull the tape measure through the "erasing head" (pic. 3d). If you then pull the tape trough the "playback head" there won't be any deviations.



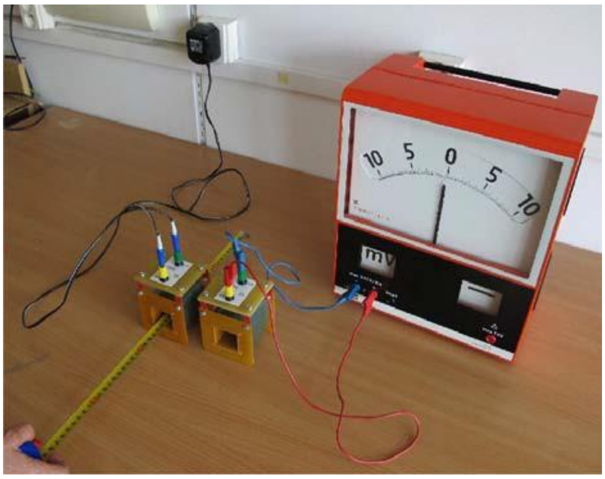
Picture 3a. A setup of a tape recorder



Picture 3b. Recording



Picture 3c. Playing the record



Picture 3d. Erasing the record

Notes: The magnetic "marks" can of course be created anywhere else on the tape. They can be closer together. However, it's good to know at which places you've made them and point out to your students the voltmeter deviations while you pull the magnetized marks through. It can be seen that the pointer deviates to the left when the tape is pulled one way and to the right when the tape is pulled the other way. It depends on the magnetic pole with which you've made the mark. This experiment as a whole can further students' understanding of the principle of electromagnetic induction.

It's necessary to find the right range of the voltmeter. A classical pointer voltmeter is better than a digital one. A pointer deviating from left to right is much more illustrative than a rapidly changing number on a digital screen with a minus or a plus sign.

The principle of erasing the magnetic record can be used as a (naïve) demonstration of what happens in a ferromagnetic material in a magnetic field. If we touch the metal tape with one pole of our bar magnet magnetic domains in the material orient themselves in the direction of the magnetic field of our magnet which creates a sort of "local permanent magnet" inside the tape. In the neighboring magnetic mark these domains are oriented the opposite way because we used the other pole of our bar magnet. If you then pull the tape through the coil it's like you're pulling a magnet through. Voltage is induced between both ends of the coil. Pulling the magnetized tape through a coil with alternating current disrupts magnetic domains because of the rapidly changing magnetic field. The tape then acts as a non-magnetized piece of ferromagnetic material.

Of course it's not necessary to use a tape measure. You can use a regular steel measure or something similar as well. It's useful to have identifiable marks on your "magnetic tape" (in the case of the tape measure it's the scale) since it's easier to find your magnetized spots.

Cosmic sounds

This experiment can serve as an entertaining addition to lessons about acoustics. Students will probably enjoy this experiment and they may try creating similar sounds at home.

Apparatus: cans of various sizes, a long metal spring, metal "mega-spring" (you can find this in various science centre shops or even in some toy stores), a nail, a hammer

Procedure: Create a small hole in the middle of the bottom of the can using hammer and nail. The hole should be just a little wider than the wire of our spring. Pull the end of our string through the hole so that the spring hangs down the bottom of the can (outside of the can). You don't need to bother with securing the string against falling out of the can. If you pull the end of the spring far enough it will hold without any help. Shake the can with the hanging spring, bump the end of the spring on the floor, run down the stairs and drag the spring behind you on the stairs, run your fingers on the spring,... You are going to hear some interesting sounds.

Use two cans and connect them with the mega-spring. In a pair hold each can and leave the spring hanging between you and poke it with your fingers (or keys and other things). You are going to hear "cosmic sounds". The experiment setup is shown on pictures 4 and 5.

Picture 4. Cosmic sounds I

Picture 5. Cosmic sounds II

A regular bucket with a drilled hole in the bottom and a string could be used as another way to produce these sounds. Hold the bucket in one hand, take a wet piece of cloth and grab the string with it. Slide your hand down the string. This will also create some strange noises similar to a cow mooing.

Notes: In the past, when computers weren't as advanced as now, these were the ways to create sound effects for sci-fi movies. As a voluntary homework, students can create similar weird sound sources at home, record the sounds they manage to conjure and hold an exhibition of cosmic sounds.

What are two ears good for

The answer to this question is obvious. Two ears allow us to recognize the direction from which a sound is coming. The sound travels a different distance to each of your ears which allows our sophisticated sense of hearing to figure out the place from which the sound is coming from (a cheeky student might offer a different answer, saying we have one ear as a spare in case the other one gets damaged – well… there might be something true about that).

If you think about the small difference between the distance a sound has to travel to our left ear and the distance to our right ear, you might wonder; what is the smallest difference of these distances our sense of hearing is able to recognize. The answer lies in our next experiment.

Apparatus: a garden hose (a bit longer than one meter), a pencil or some kind of a stick or a spoon.

Procedure: The experiment is performed in pairs. One of you takes the hose laying it on their back and holding both of its ends near their ears (picture 6). The other one of the pair taps the pencil (or a spoon) on the hose. The listeners' task is to determine from which side the sound came sooner. The listener can hold up their right or left index finger to show, which way they think the sound is coming from.

You are probably going to be surprised by the accuracy of determining the closeness of the source of the sound to your left or right ear.

Picture 4. From which side does the sound come from?

Notes: For this experiment it's convenient to prepare more hoses and let more pairs of students try it. One's own experience is much more valuable than watching someone else perform the experiment.

Garden hose is perfect for conducting sound. Therefore, you should stress that the tapping of the pencil should be moderate. A loud tap could be unpleasant or even dangerous for the listener.

Conclusion

Acoustics is a beautiful part of physics and there's room for a large number of experiments. In this text we've shown a small selection of them. We hope that you've found at least one of them engaging and that they can help you in your teaching.