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PLASMA SPEAKER AS AN EXAMPLE FOR WORK WITH GIFTED STUDENTS

B. RADULOVIĆ[1], I. KRSTIĆ[2*]

[1] University of Novi Sad, Faculty of Sciences, Department of Physics, Trg Dositeja Obradovića 3, Novi Sad, Republic of Serbia
E-mails: branka.radulovic@df.uns.ac.rs
[2] University of Belgrade, Faculty of Physics, Studentski trg 12-16, Belgrade, Republic of Serbia
E-mail: ivan@ff.bg.ac.rs, corresponding author

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Abstract. Work with gifted students implies the use of additional activities that correspond to their needs and potentials. The paper presents an example of how physics syllabus can be extended when teaching gifted students.

Key words: plasma speaker, gifted students, teaching physics.

1. INTRODUCTION

Programs and strategies for teaching physics to gifted students are versatile and basically differ in relation to general teaching conditions. Gifted education takes place in either specialized or regular, mixed ability classes. In the Republic of Serbia, specialized, gifted student classes are organized in 50 (out of 110) high schools, while only few of these classes exist in primary schools. Although the Ministry of Education puts a lot of effort in responding adequately to gifted students' needs, a certain number of the gifted are still educated in regular, mixed-ability student classes. Teaching practices in these circumstances depend on the readiness and skills of teachers to adapt subject curricula to the needs and interests of gifted students. Educational needs of the gifted impose the application of differentiated, individualized and modified curricula [1]. One way of achieving this is the model of extension of subject curricula. Extension implies the design of various additional activities and content that build upon the regular curriculum [2]. These activities and content can include information that deepen the topic being taught by applying both horizontal extension, where the content does not exceed the age level, and the vertical extension, i.e. when students learn the content intended for higher grades.

The two models offer activities organized as problem-based or project-based learning, as gifted students opt for challenges, and these activities support the use of various thinking skills and creative and critical approaches to problem solving

[3]. In other words, in order to satisfy cognitive needs of the gifted and stimulate their skills development, it is important to design such activities that require fluency, flexibility, originality, elaboration, open-mindedness and creative thinking and acting. [1]. In addition, extension models seem suitable to students, as they are not placed outside of their social surrounding, and their cognitive and academic needs can be fully met [2].

The current paper presents an example of vertical enrichment for gifted students attending third-grade of secondary education. The example encompasses and integrates knowledge related to electromagnetic and sound phenomena, supplemented with plasma state. Namely, the second-grade physics curriculum includes the notions of ideal gas state, electricity, sources of electromotive force, electrical conductivity and electric current in electrolytes, gases and vacuum. However, notions within molecular kinetic theory of gases are not related to electric phenomena. According to the third-grade physics curriculum, students study notions related to movement in magnetic field, electromagnetic induction, oscillations and sound, but a direct link between these notions is missing. Also, plasma and ionized gases are excluded from high school curriculum, they are studied at university level. Therefore, the example presented in this paper combines previously acquired knowledge with the elements of new and applicable knowledge.

Apart from integrating the students' knowledge into a coherent unit and being applied to students of both general academic and vocational high schools, the presented example represents a clear task of applying abstract thinking. Most of the processes cannot be seen by the naked eye, but their consequences are visible, such as movement of electrons through a conductor. As such, it can serve as a feedback to teachers how successfully students have acquired the taught content.

2. PLASMA SPEAKER

Conventional speaker consists of a permanent magnet and a wire coil, whose role is to drive a paper or plastic membrane (diaphragm) back and forth due to Faraday's law of induction to produce varying pressure waves. One of the problems this kind of speaker has is caused by the mass of the moving membrane along with other nonlinearities (e.g., magnetic nonlinearity and suspension nonlinearities), which transfer distortion into the sound [4-5]. Also, because of the mass and no instantaneous change of direction, this kind of speaker cannot produce a square wave. Therefore, it is the researcher's task to find a way to improve output properties of a sound making component. So far, the best performance is generated by so called "plasma speakers". The main advantage of plasma speakers is masslessness of the plasma, i.e., no requirement for a diaphragm. Also, masslessness, as characteristic of plasma speakers, is good only for high frequency sounds. Plasma cannot produce lower frequency sounds because higher amplitude of oscillations of air achievable only with bigger mass and inertia is necessary.

We can group plasma speakers into two categories. One is based on direct momentum transfer through an ion wind drawn from a corona discharge, while the other one involves a thermal mechanism [6]. By applying high voltage between electrodes (anode and cathode) you get a large electric field over the air between the electrodes. This large electric field causes an ionization of the air molecules, which starts to move in the direction of an applied electric field gradient. During their movement, ions transfer their momentum to the surrounding air, causing the oscillations of the air density around the plasma. Additional modulation of the electric field directly influences the ions moving. By this changing in time, an audio signal, i.e. a sound wave can be produced. An interesting problem for gifted students can be the comparison of plasma actuators. The plasma actuators are devices for manipulating air flow using a pair of electrodes comprising one insulated or encapsulated electrode and one electrode exposed to air [4]. If the electrode is not isolated and not cooled, it can overheat and start to melt or evaporate. Therefore, this is one of the issues that students should be careful about.

Electrons follow the electric field lines until they reach the surface of the insulator, i.e. air exposed electrode which can be positively or negatively charged [4]. If it is negative, electrons will move to the insulator surface and build up a surface charge caused by ions. If, however, it is positive, electrons will move from the insulator surface to the air exposed electrode following electric field lines. Accordingly, ions will move toward the insulator surface, i.e., nearly tangential to electric field lines. In this case, ions are responsible for the momentum transfer. Also, students can find the relationship between the electric corona discharge current, the ionic wind velocity and the applied high voltage, as well as their dependence on geometrical characteristics of the electrodes [7]. For these problems, students will use knowledge for DC, electric field, and Physics of the materials, and also gain new knowledge. Plasma actuators are interesting because they are involved in flow control applications, mostly in aerospace (e.g. aircraft wings) [4]. Therefore, students get a real problem to solve. Real problems encourage the development of creative thinking in students, thus satisfying their need for challenge.

The second type of plasma speaker operates by heating gas to produce a continually fluctuating pressure wave [8]. In this way, using the equation for ideal gas law, fluctuation of the pressure causes fluctuation of the temperature of the air surrounding the arc. Therefore, using the knowledge of molecular kinetic theory of gases, students also learns that sound is generated by the rapid expansion of an ionized channel through the air [6]. As such, plasma speaker can produce sound with high fidelity up to 150 kHz. The threshold is set by the thermal mass of the gas that is being heated [8].

For the time being, open questions arise at low frequencies, less than 2.5 kHz [4] and the production of nitrogen and other oxides as well as ozone as by-products. In [6] there is some solution for reducing ozone production. Also, there are issues of distortion modeling and energy absorption of ionized gases. It is these limitations and open questions that represent the space where gifted students can find new unconventional solutions and improve existing products.

In this paper we present an experimental set-up which students and teachers can use, both for the extension of the teaching material and for practicing the builds of electrical circuits, as a preparation for the experimental task at Physics Olympiads.

2.1. EXPERIMENTAL SET-UP

For this experiment we use a laboratory made plasma speaker (Figure 1a). There are a lot of electrical schemas for plasma speaker drivers, but here we will use the most basic and the cheapest one, so everyone can reproduce it (Figure 1b). Schema contains popular IC NE555 for generating base frequency of 21 kHz for our HV Flyback transformer. This chip allows us to add additional signal modulation from our audio signal source. Resistors R1 and R4 help us to fine tune pulse-with and frequency for our driver. Key part for powering primary coil of our flyback transformer is MOSFET (IRFP460) which must be additionally cooled via massive heatsink because there is a lot of power dissipation on it and which can produce heating of the materials.

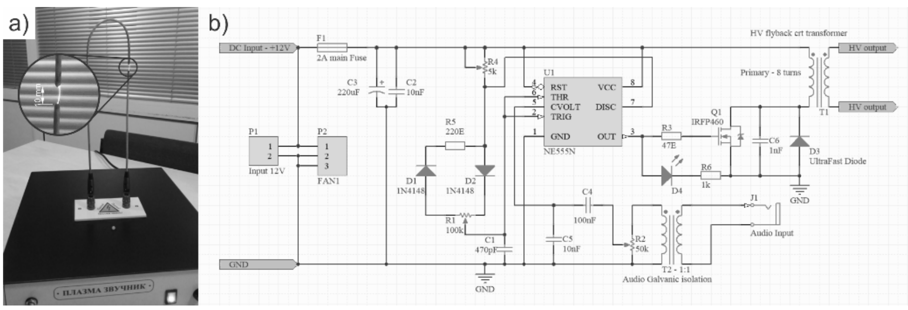

Figure 1 – (a) Laboratory made plasma speaker, and (b) electrical schema used for plasma speaker driver**.**

To record the audio signal produced by plasma speaker we use a common middle class audio speaker for computer with microphone (H390 USB). All recording is done in quiet environment. First, we must try to calibrate our system (sound reproducing device, plasma speaker and recording device). For this purpose, we send to our plasma speaker series of sinusoidal signals with the same amplitude but we do change frequency every two seconds in range of 500 to 5000 Hz, with step of 100Hz. We do this with tone generator (TG), but it can also be done via computer and program for simulating TG. To see the result of this recording, we change our recordings from time domain into frequency domain via classical fast Fourier transform (FFT) function. The result is presented in Figure 2. In this graph it can be noticed that our system prefers frequencies above 2200Hz, as already mentioned above. This is due to the characteristics of plasma and resonance of our HV flyback transformer.

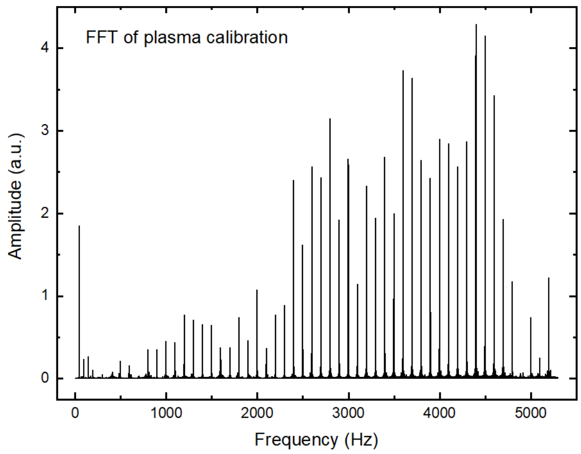

Figure 2 – FFT of discrete input frequency signal for system calibration**.**

Knowing this, now we can record our melody through the plasma speaker and compare it to the original source signal. The results are presented in Figure 3. Comparing Figures 3a and 3b we can see that plasma speaker can produce original melody very well, but it also makes additional background noise. This noise can be caused by various factors, such as geometry of electrode, gap between them, additional movement of air. If we want to avoid dancing of electric arc across the surface of electrode, the electrode should be pointy. Distance between electrodes is mainly proportional to the voltage that is on the end of the flyback transformer which can be calculated from Paschen's law. If the distance is too big, an electric arc will not form. The electric arc for plasma speaker must be protected from local air movement as it may cause shorter interruptions. For this, it can be used a piece of cardboard around three sides and which, also, can act as a sound rectifier. Comparing Figures 3c and 3d, FFT of original melody and melody recorded over plasma speaker, one can see again that the plasma speaker filters lower frequencies, so upper frequencies come to the fore. This is something we expect and has a direct correlation with our calibration method.

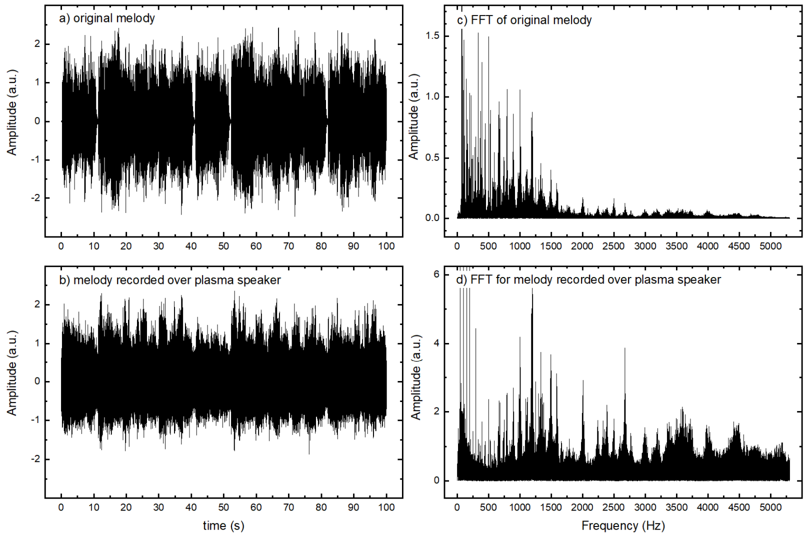

Figure 3 – Comparison of a) audio spectra of original melody and b) audio spectra for same melody recorded via plasma speaker and microphone along with c) FFT of original melody as well as d) FFT for melody recorded over plasma speaker**.**

Using our discrete calibration and converting it to a curve, we can try to restore original melody from the melody recorded via plasma speaker. We just need to divide FFT of melody recorded over plasma speaker (Figure 3d) with it. The results are presented in Figure 4. For making a comparison, we duplicate the graph from Figure 3c.

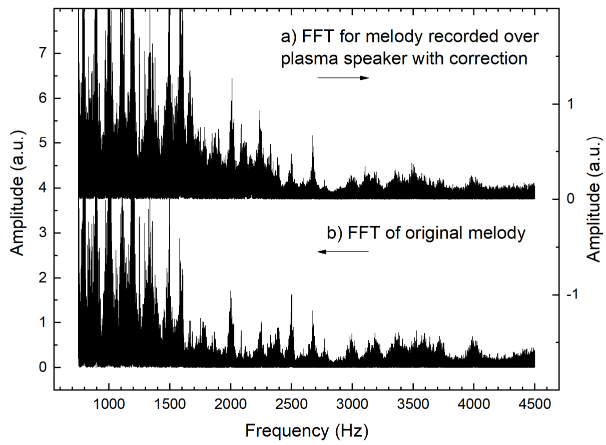

Figure 4 – Comparison of FFT audio spectra recorded over plasma speaker with correction and FFT of original melody.

As it can be seen on Figure 4, the signal reproduction is very good.

3. CONCLUSION

After identifying gifted students, one of the main issues in gifted education is finding adequate modes of teaching and learning that will stimulate their cognition and a number of other skills [3]. The paper presents an example of vertical extension of the teaching material. According to [2], extension models are very useful as they allow the gifted to fulfill their cognitive needs without being moved to a new social environment. The example presented here implies combining the knowledge of electricity, electric circuits and sound, and at the same time provides new knowledge related to plasma. Plasma speakers, similar to conventional speakers, cause modulation in the density of particles in the air around the speaker. The difference between them is in the range of frequencies they can produce without distortion caused by the mass and nonlinearity of the magnetic field. Although plasma speakers have shown as a better option, there are still some questions that remain open, such as additional extension of the frequency range, referring primarily to lower frequencies. If we adopt the definition that a gifted child is the one that excels in creative thinking and abstract reasoning, then they should be given unsolved problems as these encourage them to search for unconventional solutions.

4. ACKNOWLEDGMENTS

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