DEMONSTRATION OF DAMPED ELECTRICAL OSCILLATIONS

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Abstract. Introducing mechanical oscillations in schools is a fairly simple and easy experimental feasible task. To demonstrate electromagnetic oscillations, we have difficulty in understanding by students. The explanation of electromagnetic circuits is more abstract. We offered an experiment where we make electromagnetic oscillations obvious and understandable to students. In our experiment we used the software and interface of the AMSTEL Institute (AMSTEL Institute – Amsterdam Mathematics, Science and Technology Education Laboratory) as well as elements from the sets of experimental tasks from the Physics Olympiads organized by the Sofia branch of physicists.

Keywords: demonstration experiment; damped electrical oscillations

Introduction

If we go in the park and see the kids enjoying on their swings we have clear envision for their movement shown as mechanical oscillation. Suitable device of the system swing – kid who oscillates is a parallel connected coil with electrifying condenser. Our mission is to make visible "virtual wobble" of free electrons trough the coil.

Harmonic electric oscillations are oscillations in which the change of the characteristic physical quantity (in this case electric: voltage or current) over time takes place according to a law that can be described by the function as in other harmonic oscillations

$$y = A \cdot \sin(\omega t + \varphi) \qquad (1)$$

The reason for starting electrical oscillations in our demonstration experiment is the initial energy of the capacitor given by its charge, Figure 1 b given by equation:

$$W = \frac{CU^2}{2} \qquad (2)$$

Left alone in such a state the capacitor begins to empty because its plates are connected to the ends of the coil. The charge on the capacitor decreases and an electric current flows. The current flowing through the coil creates a magnetic field that has energy given by the equation:

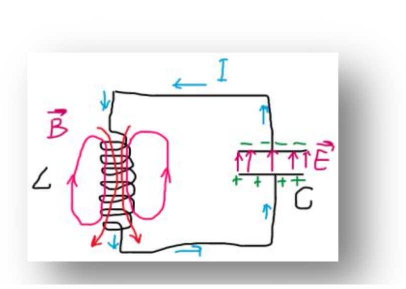
$$W_L = \frac{LI^2}{2} \qquad (3)$$

The total electricity of an electric oscillator is the sum:

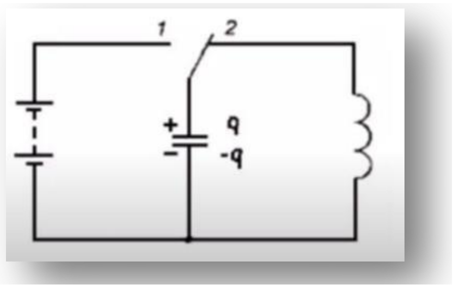
$$W = \frac{CU^2}{2} + \frac{LI^2}{2} \qquad (4)$$

In real electric oscillator circuits there is always some active resistance where the generated electrical oscillations are attenuated and disappear over time.

Our goal in the demonstration is to make the muted electrical oscillations visible.



a



b

Figure 1. Schematic diagram of closed electric oscillator circuit.

Principle of operation

The elements used to construct 2 electrical circuits of an oscillator are shown in Figure 2

Figure 2. Switch, coil with inductivity 200 mH and condensers with capacity 4,7 µF and 220 µF.

The real schematic diagram of the electric oscillation circuit is shown in Figure 3. With the help of the switch, setting in position 1 we charge the condenser. Throwing over position 2 we enable to flow the electric current trough the coil, explaining that this process is periodic: the direction of the electric current at the beginning is one, and its direction is from "+" to "-", then in reverse the direction, so there is a periodic change of the electric field between the condenser plates. So, the current that flow in one direction, though the coil, generates a field of magnetic induction with one direction and reverse. It is clear that the coil, the conductor whereof is made the coil also has an electric resistance which disables infinity long duration of those changes and enable smothering.

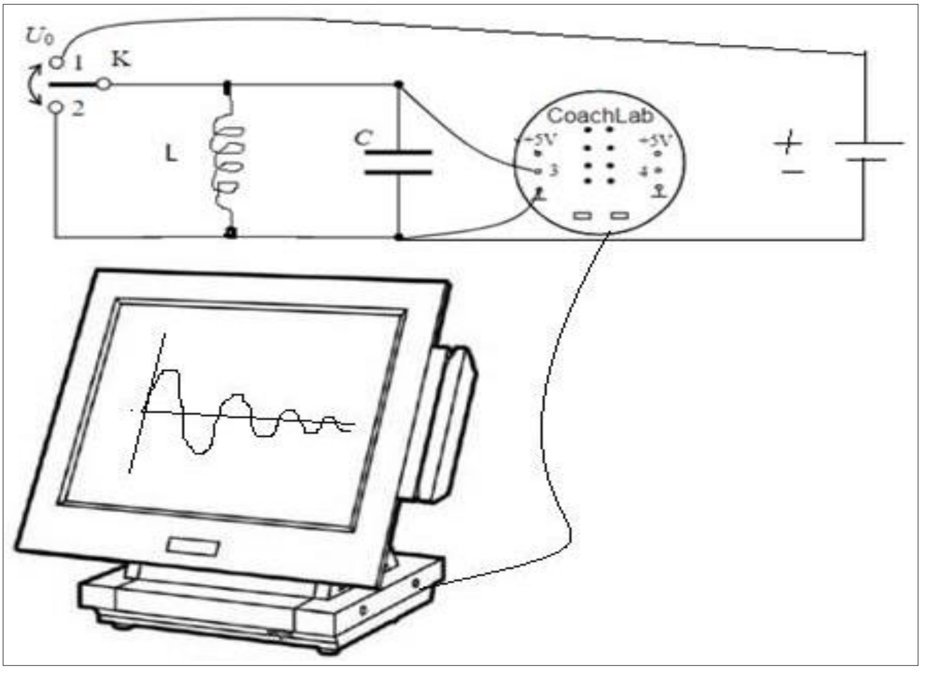


Figure 3. Electrical schematic diagram with connection of electric oscillation circuit to interface who use software package of AMSTEL, Coach 5.

In the software package of AMSTEL we have an opportunity for parallel connection of voltmeter with the ends of the condenser i.e. the coil. A graphic voltage dependence of time *U* (t) can be created. In this way, the position 1 and 2 of the switch can be noticed very well, Figure 4.

The upper parallel line of the graph shows the value of the voltage reached by the capacitor during its charging (Figure. 4), and corresponds to position 1 of the switch. When setting the switch to position 2, the appearance of attenuated electric oscillations has been already noted.

Besides, the graph can be used to determine the period of attenuated oscillations. When changing the values of the coil and the capacitor, several combinations can be made, i.e. more electric oscillatory circuits, video of them as well as to check the theoretically calculated periods and frequencies of the obtained oscillations. The attenuation factor can also be calculated as a relationship between two consecutive amplitudes, Figure 8.

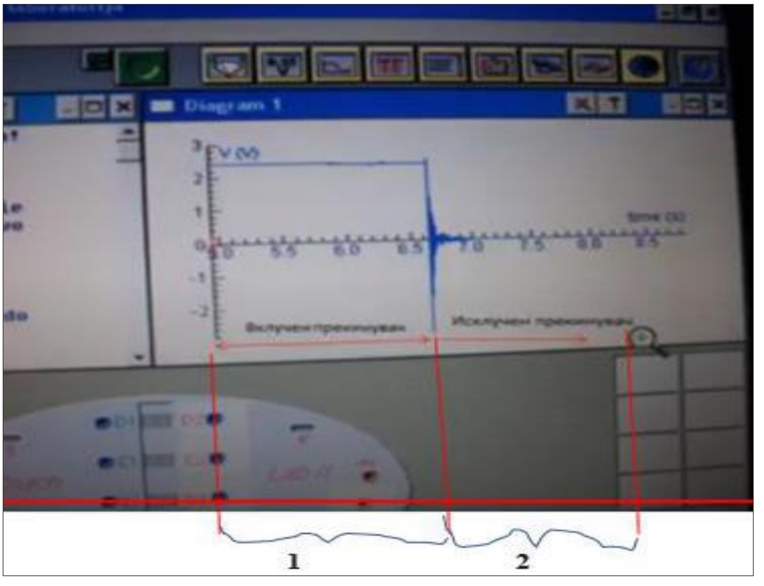


Figure 4. Notation of electrical changes when the switch is turned on and turned off

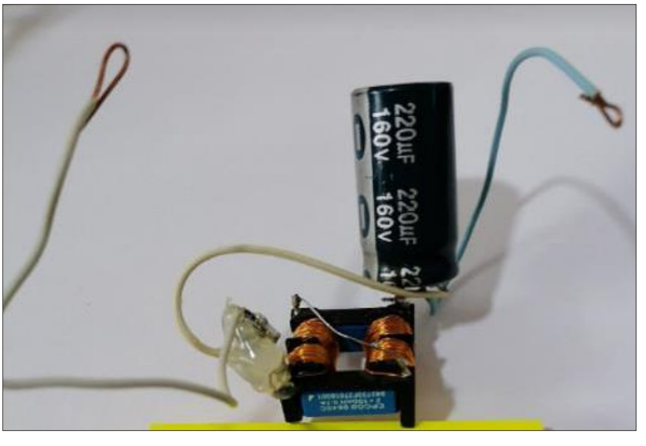


Figure 5. Electric oscillator circuit with coil 200 mH and electrolytic capacitor with a capacity of 220 µF

Dragging part 2 of the graph gives the following image, figure 6.

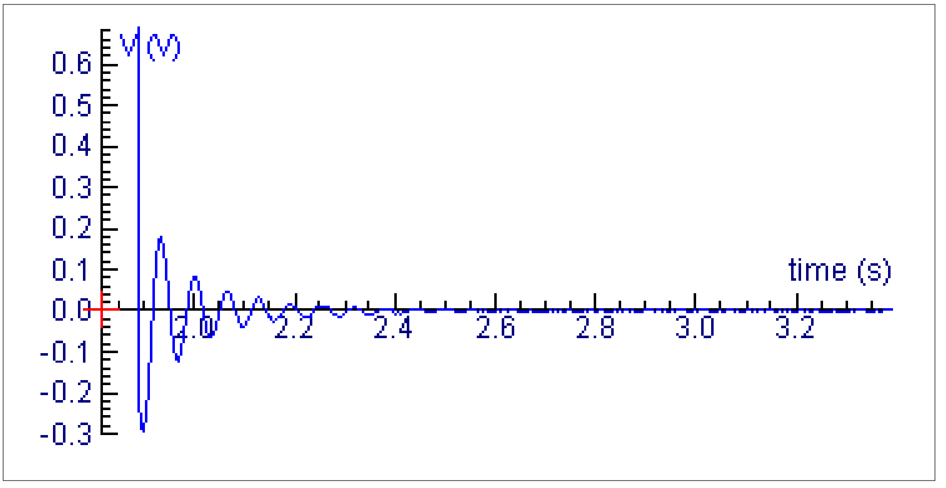


Figure 6. Periodic voltage change over time, U-t dependence

$$f = \frac{1}{T} = \frac{1}{2\pi\sqrt{LC}} \quad (5)$$

L_1=200 mH, C_1=220 µF

$f_1 = 23{,}9$ Hz

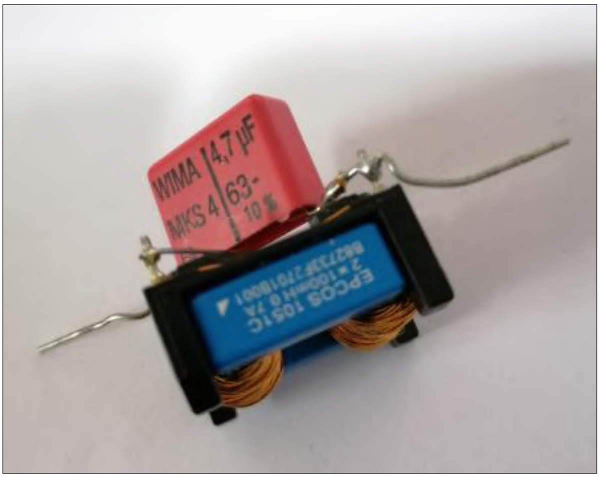


Figure 7. Electric oscillator circuit with coil 200 mH and electrolytic capacitor with a capacity of 4,7 µF

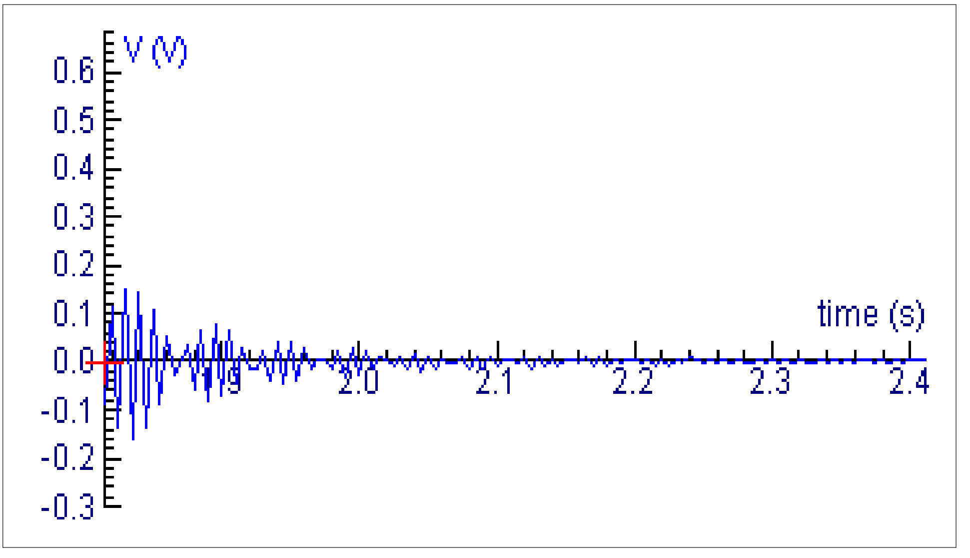


Figure 8. Periodic voltage change over time, U-t dependence

$$f_2 = 164{,}16\ \text{Hz}$$

Beats appear in the second oscillatory circuit, which are also periodic and damp.

The equation with which the attenuated electric oscillations are expressed is expressed by the equation 6:

$$U(t) = U_0 e^{-\frac{\omega t}{2Q}} \cos(\omega t \sqrt{1 - \frac{1}{4Q^2}} + \varphi) \qquad (6)$$

An additional interesting demonstration is the inclusion of a piezo electric headset, connected in parallel to the electric oscillator circuit. Generated electrical oscillations that have a frequency in the range of 20 Hz to 20 000 Hz will be recorded by the piezoelectric handset.

The ring-down method[1]

The ring-down method is extremely simple: first you have to “shake” the resonator someway to make it oscillate at its natural frequency. Then, while observing the amplitude e of the oscillations decrease, count how many cycles it takes to halve the amplitude and multiply this number by 4.53 to find *Q*, equation 7.

$$Q = \frac{\pi n}{ln(2)} \cong 4{,}53 \cdot n \qquad (7)$$

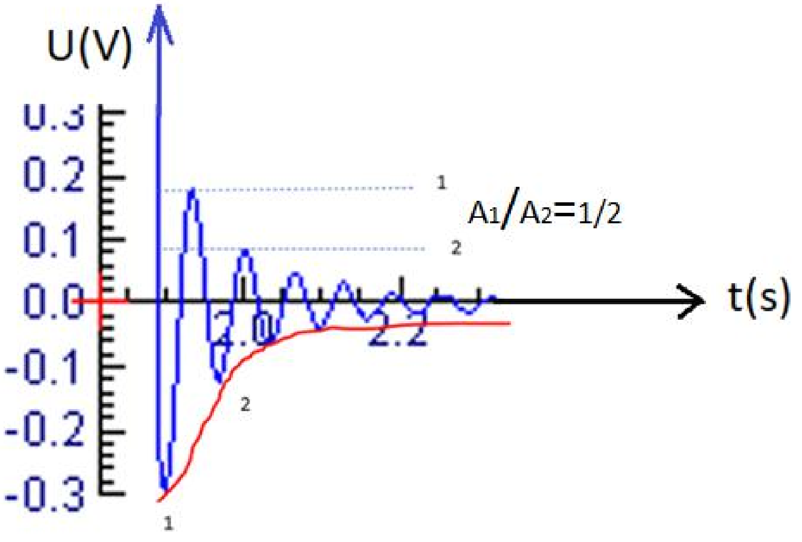


Figure 9. Counting the periods until the amplitude is reduced to a half on a $Q = 9$ tank circuit.

$$Q = \frac{\pi n}{\ln(2)} \cong 4{,}53\, n, \text{ hence the result } \quad Q_1 = 4{,}53 \cdot 2 = 9$$

Conclusion.

Experiments and demonstrations of physical phenomena are necessary for physics as a science and a school subject in education to be attractive to students. The competition "Devices in the Physics Cabinet" as well as the Experimental Physics Olympiads organized by the Sofia Branch of Union of Physicist of Bulgaria are an ideal opportunity for that.

NOTES

1. https://www.giangrandi.ch/electronics/ringdownq/ringdownq.shtml
2. http://www.ddp.fmph.uniba.sk/~hola/index_file/c5/tech_info/coach5-CL2.htm
3. http://www.ddp.fmph.uniba.sk/~hola/index_file/c5/tech_info/coach5-CL2.htm
4. https://salfordacoustics.co.uk/sound-waves/oscillation/free-oscillations-forced-oscillations-and-resonance
5. https://www.giangrandi.ch/electronics/ringdownq/ringdownq.shtml

REFERENCES

Svoreny, R. (1986). *Elektronika shag za shagom*. Moskva: Detska literatura

Zupančič, I. (1985). *Fizikalni Praktikum II*. Ljubljana: Društvo matematikov, fizikov in astronomov.

Borisov, M. (1965). *Fizika, Chast I, Mehanika*. Sofia: Nauka i izkustvo.

Jonoska, M., Ristova-Vaseva, M., Zajkov, O. & Jakimovski, D. (2009). *Fizika za II godina na reformiranoto gimnazisko obrazovanie.* Skopje: Prosvetno delo.

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