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PERFORMANCE OF THE LABORATORY WORK "OSCILLATIONS IN L-R-C SERIES CIRCUIT" BY USING MATLAB SOFTWARE PACKAGE

Abstract. The article suggests the calculation and visualization of oscillations that occur in the L-R-C series circuit. It contains the formulation of the problem, the physical analog and mathematical model of the process and the Matlab software program codes describing the process. There are graphs of the current through the circuit versus time, of the voltage across the inductor and across the resistor versus time. Because of the resistance the electromagnetic energy in the circuit is dissipated and converted to internal energy of circuit materials. The article also contains the assignments for students' individual work which require them to make comparative conclusions about various oscillations that occur when parameters of the circuit change.

Keywords. L-R-C series circuit, inductance, capacitor, resistor, power source, voltage, current.

Introduction

Nowadays all educational institutions of Kazakhstan are provided with computer hardware and software, interactive boards and internet. Almost all teachers have completed language and computer courses for professional development. Hence the educational institutions have all conditions for using computer training programs and models for performing computer laboratory works. In recent years the new computer system Matlab for performing mathematical and engineering calculations is widely used in university and engineering researches throughout the world [1-7]. Unfortunately, the numerical calculations which are carried out by students often are done by means of the calculator that is almost manually. Modern computers are frequently used only for presentation of the work. Actually students should be able not only to solve these or other engineering problems, but also do them by using modern methods, that is, using personal computers.

Students of the physics specialties 5B060400 and 5B011000 successfully master the discipline "Computer modeling of physical phenomena" which is the logical continuation of the disciplines "Information technologies in teaching physics" and "Use of electronic textbooks in teaching physics". The aim of this discipline is to study and learn the MATLAB program language, acquaintance with its huge opportunities for modeling and visualization of physical processes.

In our early works [8-28] we have shown the potentials of the Matlab software for modeling and visualization of physical processes in mechanics, molecular physics, electromagnetism and quantum physics where it have been used for solving the ordinary differential equations (ODE), for visualization of the equipotential lines of the systems of charged conductors and of the motion of charged particles in electric, magnetic and gravitational fields.

The present article is devoted to calculation and visualization of oscillations in the L-R-C series circuit by using the MATLAB software.

Formulation of the problem. The L-R-C circuit contains an inductor with inductance *L*, a capacitor with capacitance *C*, a resistor with resistance *R* and a power source. Let's consider electromagnetic processes that occur in the L-R-C series circuit.

Physical analog. Let's consider the L-R-C circuit with definite parameters (Fig. 1). The resistor has only ohmic resistance, the inductor has only inductive resistance, the capacitor has only capacitive resistance. The source generates a sinusoidal emf (electromotive force), the internal resistance of the source is negligibly small compared with the circuit resistance. The circuit doesn't radiate.

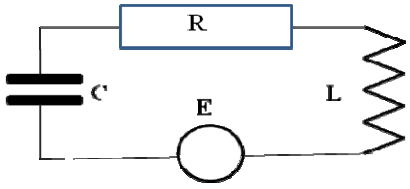

Figure 1 - The diagram of the L-R-C circuit

Parameters of the modeling. The capacitance of the capacitor, the inductance of the inductor, the ohmic resistance of the resistor, the amplitude and frequency of the source's emf.

Mathematical model. According to Kirchhoff rules, the algebraic sum of voltage drops across all elements of the circuit is equal to the source's emf. Therefore, the mathematical model of the circuit is:

$$L\frac{dI}{dt} + RI + \frac{1}{C}\int Idt = E,$$

$$L\frac{dI}{dt} + RI + \frac{1}{C}\int Idt = E_0 \cos\omega t$$

To get rid of integration, we will differentiate the left-side and right-side of the above equation with respect to time:

$$\frac{d^2I}{dt^2} + \frac{R}{L}\frac{dI}{dt} + \frac{1}{LC}I = -E_0\frac{\omega}{L}sin\omega t. \quad (1)$$

Here *R* is ohmic resistance of the resistor with SI unit Ohm (Ω), *L* is the inductance of the inductor with SI unit Henry (*H*), *C* is the capacitance of the capacitor with SI unit Farad (*F*), *I* is the current through the circuit with SI unit Ampere (*A*) and $E = E_0 cos\,\omega t$ is the source's emf which as a function of time changes with frequency ω and amplitude E_0.

By changing variables

$$I = z_1,\ \frac{dI}{dt} = \frac{dz_1}{dt} = z_2,\ \frac{d^2I}{dt^2} = \frac{dz_2}{dt} = -\frac{R}{L}\frac{dI}{dt} - \frac{1}{LC}I + E_0\frac{\omega}{L}\sin\omega t$$

We will reduce the equation (1) to the system of two differential equations of the first order

$$\frac{dz_1}{dt} = z_2,\ \frac{dz_2}{dt} = -\frac{R}{L}z_2 - \frac{1}{LC}I + E_0\frac{\omega}{L}\sin\omega t \quad (2)$$

For calculation of the right-sides of the system of the differential equations (2) we create m-file titled "contur.m".

```
function dzdt=contur(t,z)
global  R C L E0 w
dzdt=[z(2); -R/L*z(2) – 1/(L*C)*z(1)+wE0*sin(w*t)/L];
```

In the command line we write the codes of the program Matlab

```
global  R C L E0 w
>> R=0.3;
>> L=1;
```

```
>> C=0.25;
>> z0=[1;0];
>> t0=0;
>> w0=1/sqrt(L*C);
>> T=2*pi/w0;
>> E0=0;
>> w=1;
>> tmax=5*T;
>> dt=[t0 tmax];
>> [t z]=ode45(@contur,dt,z0);
>> subplot(3,1,1);
>>  plot(t,z(:,1),'LineWidth',2);
>>  title('current through the circuit','FontName','Arial Unicode MS')
>> ylabel('I,A', 'FontName', 'Arial Unicode MS')
>> grid on
>> subplot(3,1,2);
>> UL=z(:,2)*L;
>> plot(t,UL,'LineWidth',2)
>> title('Voltage across the inductor', 'FontName','Arial Unicode MS')
>> ylabel('UL,B', 'FontName', 'Arial Unicode MS')
>> xlabel('время,с', 'FontName','Arial Unicode MS')
>> grid on
>> subplot(3,1,3);
>> UC=z(:,1)*R;
>> plot(t,UC,'LineWidth',2)
>> title('Voltage across the resistor,'FontName','Arial Unicode MS')
>>  ylabel('UR,B', 'FontName', 'Arial Unicode MS')
>> xlabel('время,с', 'FontName','Arial Unicode MS')
>> grid on
```

Results are presented in the fig.2

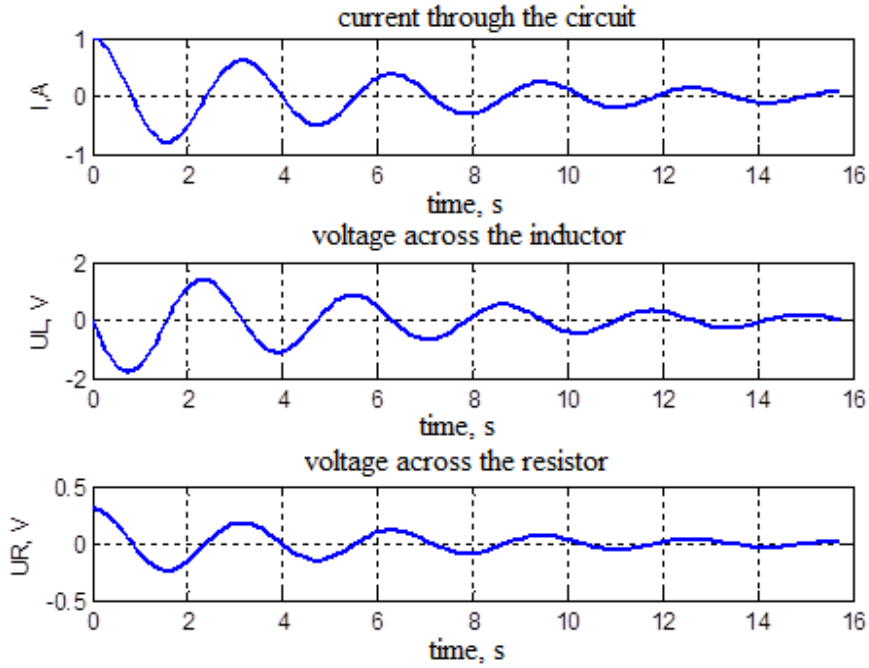

Figure 2 -The graphs of the current through the circuit and voltage across the inductor versus time; the graph of the voltage across the resistor versus time

At the ohmic resistance of the resistor of R = 0.3 Ω the oscillations are damping because of conversion of electric energy to internal energy of the resistor. The voltage across the resistor is in phase with the current in the resistor, while the voltage across the inductor leads the current by 90°.

Assignments for individual work:

1. Specify the value of ohmic resistance of the resistor to be R=0. Obtain the graphs and make a conclusion about influence of resistance of the resistor on the nature of oscillations.
2. Increase the resistance of the resistor and make a conclusion about the degree of damping as a function of the ohmic resistance.
3. Increase the magnitude of the inductance in the circuit by 4 times. How did the oscillation frequency change? Conduct similar researches with the capacitance.
4. Specify the resistance of the resistor to be greater than its critical magnitude $R_c = 2\sqrt{L/C}$ and observe the transformation of the damping process to aperiodic one.
5. Connect the circuit to the source ($E_0 > 0$). Observe transition processes in the circuit. By gradually increasing the time of the experiment t_{max}, try to obtain the stationary oscillations.
6. By gradually changing the frequency ω of emf specify its magnitude to be equal to the natural frequency of the circuit $\omega_0 = 1/\sqrt{LC}$. Observe the increase in the amplitude of the oscillation (resonance). Compare the magnitude of emf with the magnitude of the voltage amplitude across the inductor.
7. Draw the graph of the voltage across the capacitor. For this purpose make changes in the code of the program. The voltage across the capacitor is defined by the expression $U_C = \frac{1}{C}\int Idt$.
8. Draw the graph of the magnetic field energy, produced by the current through the inductor $W_m = \frac{1}{2}LI^2$. Compare the frequencies of oscillations of the magnetic field energy and the voltage across the inductor.

Conclusion: The calculation and visualization of oscillations that occur in the L-R-C series circuit with definite parameters is performed using Matlab software. The article contains the formulation of the problem, the physical analog and mathematical model of the process and the Matlab software program codes describing the process. There are graphs of the current through the circuit versus time, of the voltage across the inductor and across the resistor versus time. Because of the resistance the electromagnetic energy in the circuit is dissipated and converted to internal energy of circuit materials. The article also contains the assignments for students' individual work which require them to make comparative conclusions about various oscillations that occur when parameters of the circuit change.

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«ТЕРБЕЛМЕЛІ КОНТУРДАҒЫ ТЕРБЕЛІСТЕРДІ СИПАТТАУҒА» АРНАЛҒАН КОМПЬЮТЕРЛІК ЗЕРТХАНАЛЫҚ ЖҰМЫСТЫ ОРЫНДАУДЫ ҰЙЫМДАСТЫРУ

Аннотация. Тербелмелі контурдағы тербелістерді сипаттауға арналған компьютерлік зертханалық жұмысты орындауды ұйымдастыру ұсынылады. Мәселені тұжырымдау, контурда жүретін процестердің физикалық және математикалық моделдері, оларды Matlab жүйесінде іске асыратын бағдарлама кодтары келтірілген. Контурдағы токтың, индуктивтік катушкадағы және резистордегі кернеу түсуінің уақытқа тәуелділік графиктері берілген. Резистрдің кедергісі болған жағдайда тербелістер өшпелі сипатта болатыны байқалады. Үйткені резисторда энергия жұтылады. Өз бетінше орындауға арналған тапсырмалар ұсынылып, контур элементтерінің кейбір параметрлерін өзгерткен жағдайлардағы тербеліс сипаттары туралы қорытынды жасау ұсынылады.

Түйін сөздер. Тербелмелі контур, индуктивтілік, конденсатор, резистор, ток көзі, кернеу, ток.

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ОРГАНИЗАЦИЯ ВЫПОЛНЕНИЯ КОМПЬЮТЕРНОЙ ЛАБОРАТОРНОЙ РАБОТЫ «ПРОЦЕССЫ, ПРОИСХОДЯЩИЕ В КОЛЕБАТЕЛЬНОМ КОНТУРЕ»

Аннотация. Предлагается расчет и визуализация характера колебаний, происходящие в последовательном колебательном контуре. Приведены формулировка задачи, физическая и математическая модели процесса, коды программы, реализующие процессы в программной среде Matlab. Построены графики зависимостей силы тока в контуре, напряжений на катушке индуктивности и падения напряжения на резисторе от времени. При наличии сопротивления резистора колебания являются затухающими, что связано с поглощением энергии резистором. Предложены задания для самостоятельной работы и проведение сравнительных выводов о характере колебаний при изменений отдельных параметров элементов контура.

Ключевые слова. Колебательный контур, индуктивность, конденсатор, резистор, источник, напряжение, ток.

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