THE SUPPORT OF SOLVING PHYSICAL PROBLEM BY THE MEANS OF MATHEMATICAL SOFTWARE

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Abstract

At the present time the great emphasis is put on making accessible new knowledge to students through information and communication technologies in effort to facilitate and introduce objects, phenomena and reality. Information and communication technologies complement and develop traditional methods such as direct observation, manipulation with objects, experiment. It is justified mainly at teaching natural sciences. The possibilities of physical problem solution by the use of mathematical software are presented in the paper.

Key words: information and communication technologies, physical problem solution, MS Excel, Matlab.

1 Introduction

Information and communication technologies currently present a set of modern means that are used for preparation, processing and distribution of data and information, but also process control with the aim of achieving more effective results and searching for optimal problem solutions at various fields and areas of human activities. Information and communication technologies significantly influence even university education. Information and communication technologies provide incomparably bigger information basis as it was several years ago. This gradually changes the style of teaching and makes teachers implement new technologies not only in direct pedagogical activity, but also at its preparation. Implementation of information and communication technologies into education enables new forms of university studies. We can stimulate the interest of students in studies of natural science subjects as mathematics, physics, chemistry, create conditions for educational individualization and improve conditions to raise the quality of education by a suitable combination of traditional and modern teaching methods.

2 Utilization of mathematical software at physical problem solution

In teaching physics there exist possibilities for effective and suitable integration of information and communication technologies into schooling system. One of them is physical problem solution with the support of computer. This paper concretely presents the solution of physical problem from the part Physics – Power and Magnetism by the use of mathematical software MS Excel a Matlab.

Problem assignment: Figure out the currents in individual circuit branches in Fig. 1, if source voltage and resistance are: U_{01}=10 V, U_{02}=20 V, U_{03}=15 V, U_{04}=10 V, R_1=10 Ω, R_2=15 Ω, R_3=30 Ω, R_4=20 Ω, R_5=10 Ω, R_6=15 Ω, R_7=10 Ω.

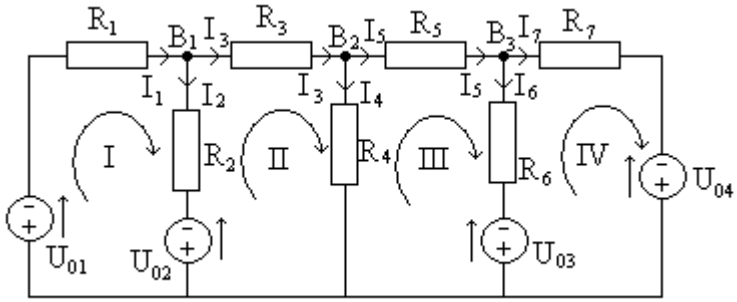

Fig. 1: *Circuit.*

Solution: Kirchhoff´s rules are used to figure out the currents in the circuit [1]. The first of Kirchhoff´s rules describes the law of electric charge preservation: *The sum of all the currents flowing into the junction point must equal the sum of all the currents leaving the point*, i.e. $\sum_{k=1}^{n} I_k = 0$. The second of Kirchhoff´s rules forms the law of electric energy preservation for electric circuits: *Algebraic sum of electromotive voltages in any closed part of the electrical network is equal to the sum of ohmic voltages at individual branches of this closed part*, i.e. $\sum_{i=1}^{m} U_{ei} = \sum_{k=1}^{n} R_k I_k$.

Based on the first and the second of Kirchhoff´s rules (Fig. 1) for the currents and electromotive voltages, it is valid

$$\begin{aligned} B_1: &\quad I_1 - I_2 - I_3 = 0 \\ B_2: &\quad I_3 - I_4 - I_5 = 0 \\ B_3: &\quad I_5 - I_6 - I_7 = 0 \end{aligned}$$

$$\begin{aligned} I: &\quad R_1 I_1 + R_2 I_2 = U_{01} - U_{02} \\ II: &\quad -R_2 I_2 + R_3 I_3 + R_4 I_4 = U_{02} \\ III: &\quad -R_4 I_4 + R_5 I_5 + R_6 I_6 = -U_{03} \\ IV: &\quad -R_6 I_6 + R_7 I_7 = U_{03} - U_{04} \end{aligned}$$

The set of 7 equations on 7 unknown quantities I_1, I_2, ..., I_7 was obtained. Numeric values are inducted for the known quantities and we have

$$\begin{aligned} I_1 - I_2 - I_3 &= 0 \\ I_3 - I_4 - I_5 &= 0 \\ I_5 - I_6 - I_7 &= 0 \\ 10 I_1 + 15 I_2 &= -10 \\ -15 I_2 + 30 I_3 + 20 I_4 &= 20 \\ -20 I_4 + 10 I_5 + 15 I_6 &= -15 \\ -15 I_6 + 10 I_7 &= 5 \end{aligned}$$

3 Problem solution by means of MS Excel

The problem can be solved analytically, which is not easy in case that there is a bigger number of equations. It is much easier to solve the set of 7 equations on 7 unknown quantities numerically by the use of the MS Excel Solutionist [2]. From the assignment and solution of the problem in the Solutionist we have (Fig. 2):

	A	B	C	D	E	F	G
1	Výpočet prúdov v obvode - riešenie sústavy 7 rovníc						
2				o 7 neznámych			
3	1	-1	-1		0		
4	1	-1	-1		0		
5	1	-1	-1		0		
6	10	15			-10		
7	-15	30	20		20		
8	-20	10	15		-15		
9	-15	10			5		
10							
11	I_1 =	I_2 =	I_3 =	I_4 =	I_5 =	I_6 =	I_7 =
12	-0,30198	-0,46535	0,16337	0,40594	-0,24257	-0,29703	0,05446
13							

Fig. 2: *Numerical solution of the set of equations in MS Excel.*

It is valid for the circuit currents that

$$I_1 = -0{,}30198\ A,\quad I_2 = -0{,}46535\ A,\quad I_3 = 0{,}16337\ A,\quad I_4 = 0{,}40594\ A,$$
$$I_5 = -0{,}24257\ A,\quad I_6 = -0{,}29703\ A,\quad I_7 = 0{,}05446\ A$$

It results from the negative values of the current that currents have reverse directions as it was selected.

4 Problem solution by means of Matlab

MATLAB presents highly efficient language for technical calculations [3]. The method of junction point voltages can be used to figure out the currents I_1, I_2, ..., I_7 [4]. For junction points B_1, B_2 a B_3 under the first of Kirchhoff´s rules and junction point voltages we have:

$$B_1: \quad I_1 - I_2 - I_3 = 0 \quad \Leftrightarrow \quad \frac{U_{01} - U_{B1}}{R_1} - \frac{U_{B1} - U_{02}}{R_2} - \frac{U_{B1} - U_{B2}}{R_3} = 0$$

$$B_2: \quad I_3 - I_4 - I_5 = 0 \quad \Leftrightarrow \quad \frac{U_{B1} - U_{B2}}{R_3} - \frac{U_{B2}}{R_4} - \frac{U_{B2} - U_{B3}}{R_5} = 0$$

$$B_3: \quad I_5 - I_6 - I_7 = 0 \quad \Leftrightarrow \quad \frac{U_{B2} - U_{B3}}{R_5} - \frac{U_{B3} - U_{03}}{R_6} - \frac{U_{B3} - U_{04}}{R_7} = 0$$

The equations can be written in the form of matrices:

$$\begin{bmatrix} 1/R_1 + 1/R_2 + 1/R_3 & -1/R_3 & 0 \\ 1/R_3 & -(1/R_3 + 1/R_4 + 1/R_5) & 1/R_5 \\ 0 & -1/R_5 & 1/R_5 + 1/R_6 + 1/R_7 \end{bmatrix} \begin{bmatrix} U_{B1} \\ U_{B2} \\ U_{B3} \end{bmatrix} = \begin{bmatrix} U_{01}/R_1 + U_{02}/R_2 \\ 0 \\ U_{03}/R_6 + U_{04}/R_7 \end{bmatrix}$$

The solution of matrices in Matlab can be used to solve such written equations. M-file *prudy.m* is formed (Fig. 3):

```
U01=10; U02=20; U03=15; U04=10;
R1=10; R2=15; R3=30; R4=20; R5=10; R6=15; R7=10;
A=[(1/R1+1/R2+1/R3), -1/R3              , 0    ;
    1/R3           , -(1/R3+1/R4+1/R5) , 1/R5 ;
    0              ,-1/R5              , (1/R5+1/R6+1/R7)];
I=[(U01/R1+U02/R2);0;U03/R6+U04/R7];
U=A\I;
```

```
I1=(U01-U(1))/R1;
I2=(U(1)-U02)/R2;
I3=(U(1)-U(2))/R3;
I4=U(2)/R4;
I5=(U(2)-U(3))/R5;
I6=(U(3)-U03)/R6;
I7=(U(3)-U04)/R7;
fprintf('\n');
fprintf('I1 = %8.5f A\n', I1);
fprintf('I2 = %8.5f A\n', I2);
fprintf('I3 = %8.5f A\n', I3);
fprintf('I4 = %8.5f A\n', I4);
fprintf('I5 = %8.5f A\n', I5);
fprintf('I6 = %8.5f A\n', I6);
fprintf('I7 = %8.5f A\n', I7);
```

Fig. 3: *M-file prudy.m for calculation of matrices and currents.*

After solution of the set of equations we have the values of junction point voltages, which are converted to the currents in the circuit branches. The result of the solution is the initiation of the script *prudy.m* and single printout of results:

```
>> prudy
I1 = -0.30198 A  I2 = -0.46535 A  I3 =  0.16337 A  I4 =  0.40594 A
I5 = -0.24257 A  I6 = -0.29703 A  I7 =  0.05446 A
```

The same values are obtained from the problem solution in Matlab as in the case of the problem solution in MS Excel.

5 Conclusion

Solution results prove that the solution of the set of equations of the physical problem by using two various mathematical software leads to the same numerical values. The solved physical problem points out the importance of intersubject relations of technical subjects.

5 Literature

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