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INTELLECTUAL TECHNOLOGIES IN THE EDUCATIONAL PROCESS AND THEIR IMPACT ON THE QUALITY OF MATHEMATICAL KNOWLEDGE

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INTRODUCTION

In recent years, Ukraine has been holding a professional discussion on the possibilities of reforming educational activities, which in the future should determine the directions for improving the technology of education. The subject of the discussion is the rapid development of artificial intelligence (AI) and its implementation and use in education. One group of scientific and pedagogical workers, who are engaged only in theoretical training of educational applicants, considers it inappropriate to use AI in the educational process due to a decrease in the interest of the educational applicants to classical classroom activities. Other educators and scientists, on the contrary, support the idea of applying AI in education because they are engaged in solving practical problems and have experience in implementing their results in various fields of activity.

In the research laboratory for materials science, one American company conducted a study of the impact of AI on innovation at example of randomized implementation of the discovery materials technology for 1,018 scientists[1]. According to the results of the study, researchers discovered 44% more materials with the help of AI. This led to an increase in the number of patents by 39% and an increase in innovation in the future by 17%. It is noted that the applied technology has a different effect on the distribution of productivity of its employees. A third of scientists do not see the benefits of using AI, and the productivity of the best ones increases twice. Completed studies demonstrate on the one hand the complementarity of algorithms and expertise in the innovation process; on the other hand the advantages of AI affect the reduction of creative potential and dissatisfaction of scientists with the insufficient level of their skills use.

So, the emergence of AI challenges not only education systems, but also scientists. There are already scientific articles and patents that are generated by AI in whole or in part, and the educational applicants use AI to perform written work and receive answers in solving academic problems. There are

[1] Aidan Toner-Rodgers. Artificial Intelligence, Scientific Discovery, and Product Innovation. URL: https://aidantr.github.io/files/AI_innovation.pdf

hot discussions around the application of AI– from the capture of AI capabilities to concerns about the reliability, potential bias of AI and the ethics of its application in education.

1. Development of the latest intellectual technologies and their impact on the quality of education

As noted above, new intellectual technologies open up new opportunities and create new problems in the field of education. On the one hand, it is personalized learning, virtual labs and smart chat bots that are ready to provide 24/7 answers[2]. Machine intelligence is able to turn uninteresting lectures into an exciting process that makes complex problems clearer and motivates for further learning. On the other hand, educational applicants are increasingly turning to AI for help when performing original work. It may lead to the loss of critical thinking skills for the new generation.

– This problem is especially acute in the study of higher mathematics and its branches like mathematical statistics and computer mathematics. In the context of intensification of training, when the vast majority of educational applicants perform tasks involving AI tools, there is need to

– study the possibilities of the best programs for solving mathematical problems;

– formulate the rules for using programs based on AI in the educational process;

– study the experience of implementing AI-based programs and the conditions for their application in the academic activities of educational institutions.

According to a list published in the online edition of Smodin, eleven mathematical problem solver programs are considered to be the best[3]. Next, their main features, pricing, advantages and disadvantages are listed.

1. Smodin Omni is a mathematical AI-solver that allows you to practice in solving problems, revealing the academic potential of users.

Payment is $12 per month.

Pros – accuracy, reliability, time saving, user-friendly interface.

Cons are limited types of problems, difficulties with solving non-standard types of problems, dependence on the users' AI.

2. Photomath is an application-scanner of mathematical problems, which allows you to instantly get a solution to the problem.

Payment – 0$ (limited functions), 69,99$/year (unlimited functions).

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[2] Ярошенко Т. Виклики штучного інтелекту для освіти й науки. URL: https://zn.ua/ukr/TECHNOLOGIES/vikliki-shtuchnoho-intelektu-dlja-osviti-j-nauki.html?fbclid=IwZXh0bgNhZW0CMTEAAR0iyCpoJkIgSz2qSjHLBlPipBWBlGpc1Q0EAi0kgoeb0UD_mYFj8pN_zoA_aem_oxfYb5tS6wvCd4JhH83Ebg

[3] Best AI Math Solvers. URL: https://smodin.io/blog/uk/best-ai-math-solvers/

Pros – ease of use, step-by-step solution, availability on IOS/Android platforms.

Cons – the limited types of problems, the inaccuracy of the solutions obtained, which is associated with difficulties in interpreting handwritten tasks; excessive dependence of users.

3. Social by Google is a platform that provides step-by-step solutions to mathematical problems and contains useful information in the form of videos, definitions, useful links that improve understanding of the solution process.

Payment is free.

Pros – accurate answers with links provided integration with Google; user-friendly interface.

Cons – limited deep learning that does not meet the needs of users with a high level of mathematical training; internet dependence of users.

4. Mathway is an online tool for solving mathematical problems based on AI.

Payment is free.

Pros – covers a wide range of problems, offering step-by-step solution; user-friendly interface.

Cons – access to step-by-step explanations requires a paid subscription; potential for abuse by users; limited autonomous functionality.

5. Wolfram Alpha is a tool for math students, which has a graphical interface and access to a repository of mathematical concepts, formulas and equations.

Payment is free.

Pros – a wide knowledge base; step-by-step solution of complex mathematical problems; a variety of data input methods (natural language, mathematical records, voice commands).

Cons – detailed information and step-by-step solutions require a paid subscription; complex interface for users without technical experience; dependence on the internet connection.

6. Maple Calculator is an AI-based tool for step-by-step solving complex mathematical problems, which has a wide range of functions and plot tools, offers educational games and puzzles that improve mathematical skills.

Payment is $6.99 per month.

Proc – advanced mathematical possibilities for solving problems at higher levels; step-by-step solution of complex mathematical problems; interactive graphics that allows you to visualize functions and 2D/3D data.

Cons – a difficult interface for users with improper mathematical training; access to full functionality requires a paid subscription; limited compatibility with some mobile devices.

7. CameraMath is a mobile AI application that offers a comprehensive solution to problems for math students.

Payment is free.

Pros – a wide range of tasks, step-by-step solutions, a simple interface.

Cons – problems with accuracy and limitations of types of tasks that are associated with character recognition; access to all functions and step-by-step solutions requires a paid subscription.

8. Brilliant is a platform for math students. It uses AI algorithms to establish personalized feedback to the user based on his own progress.

Payment is $ 13.49 per month.

Pros – interactive learning experience, which contributes to the development of critical thinking skills; high-quality content developed by experts and teachers.

Cons – the cost of subscription; limitations for experienced users; it does not solve real-time problems by focusing on providing concepts rather than solutions.

9. Microsoft Math Solver is a universal platform for solving mathematical problems, which provides step-by-step solutions and visual aids; it has the ability to recognize handwritten symbols, which allows you to check your own solutions.

Payment is free.

Pros – solves a wide range of mathematical problems that makes it suitable for use by educational applicants with different levels; available on IOS/Android and web browsers.

Cons – problems with accuracy; limited step-by-step solutions; requires an internet connection.

10. MyScript is an innovative AI-based application that is able to interpret handwritten records and provide real-time feedback.

Payment is $ 2.99 in App Store.

Pros – interactive and intuitive; supports a wide range of mathematical problems that matches different educational levels and needs.

Cons – limited free functions; random recognition errors that lead to incorrect solutions; requires training to master the interface and the program functions.

11. Symbolab is AI-based application for solving mathematical problems, which offers various calculators and tools.

Payment is free.

Pros – supports a wide range of mathematical problems, offering detailed solutions and explanations; it has a convenient interface.

Cons – a limited number of free functions; advertising and pop-up windows; low accuracy of calculations in complex problems solving.

Analyzing the existing list of programs and applications that use AI algorithms, it can be argued that none of them is perfect enough to meet the user's needs at all educational levels. Therefore, it is important to determine the boundaries of the application of AI in the academic process of educational activities, which would not interfere with the progress and self-improvement of the educational applicants, and correctly perform the function of an assistant.

Some experience in the rules of enrollment and evaluation of performed with the involvement of AI student work has already been developed both in Ukraine and abroad.

In December 2023, the National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute" approved the policy of using AI for academic activities[4]. That document defines the principles of responsible and ethical use of AI technologies in the educational process. Namely, in the original works of the educational applicants, it should be indicated where AI is used – for translation, analysis, etc. The limits of application of AI are defined in the syllabuses of the relevant educational component.

In the same 2023, the University of South Carolina in the United States, in addition to the policy of using AI for students, clear guides have been developed that explain the rules for applying AI and warn against possible risks[5]. According to information in these guides, responsibility and ethical interaction with AI mean a critical assessment of the results created by AI, as well as openness and documentation.

It is clear that the problems in education are not limited to writing student papers using AI. In the conditions of intensification of the learning process, it is necessary to maintain human intelligence, which is capable of original thinking, creative approach and is capable of scientific discoveries.

Therefore, the task of finding new approaches for learning is relevant, which allow the intelligent use of intellectual technologies and require the ability to think independently.

2. Analysis of the use of Computer Algebra Systems in the educational process and selection of the optimal software package for the study of mathematics

The analysis of existing AI tools used in the educational process has shown their ambiguous impact on the effectiveness of training. On the one hand, using AI to solve mathematical problems saves time and can be useful for better understanding of the solution process. On the other hand, the

[4] Використання ІШІ для академічної діяльності. URL: https://www.library.kpi.ua/research/vykorystannya-shi-v-akademichnij-diyalnosti/#

[5] Using generative AI in research. URL: https://libguides.usc.edu/generative-ai/introduction

involvement of AI can lead to dependence on Internet assistants and loss of ability to critical thinking skills of users. Therefore, it is necessary to offer such types of interactive activities that may be of interest to the educational applicants and contribute to their self-improvement.

Most areas of such activities relate to the development of computational thinking as a key component of education. This type of thinking, also known as algorithmic, is a technique for solving a problem by breaking it down into smaller, simpler processes that can be performed by a computer[6]. This makes it easier to understand the problems and develop solutions that work for both computers and humans.

Computational thinking relies on mathematics as its foundation[7], requiring careful study/analysis of problems and the ability to use precise language for problem formulation and solution[8]. At the same time, the breadth and depth of a person's mathematical knowledge can be diverged with his ability to create numerical algorithms for solving applied problems. But the ability to formulate and solve a problem using software code is the basis of computational thinking.

In order to solve problems by algorithmization with the involvement of programming technology, it is necessary to choose the environment in which the corresponding program code can be executed. In solving mathematical problems, such environment is computer mathematics (CMS) and computer algebra systems (CAS). These systems are a set of methods and tools that provide the algorithm development for solving problems of any complexity. At the same time, CMS is typically used for numerical calculations that are performed with a high level of visualization of all stages of the solution. CAS is used to implement symbolic transformations of algebraic expressions and perform various mathematical operations.

Modern CAS contain functions from all sections of mathematics, support interactive visualization, have their own programming languages, allow you to combine algorithms, mathematical formulas, text, graphics, animation in one file[9].

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[6] Обчислювальне мислення: новий спосіб мислення. URL: https://hashdork.com/uk/обчислювальне-мислення/

[7] Xue, D, Chan, Y. Solving applied mathematical problems with MATLAB. URL: https://www.taylorfrancis.com/books/mono/10.1201/b17177/solving-applied-mathematical-problems-matlab-dingyü-xue-yangquan-chen

[8] МакФарланд А. Що таке обчислювальне мислення. URL: https://unite.ai/uk/що-таке-обчислювальне-мислення/

[9] List of computer algebra system. URL: https://en.wikipedia.org/wiki/List_of_computer_algebra_systems

According to the online publication Slant, the best of the available CAS (43 positions in the list) are the following twelve[10]. More information about their capabilities is in the list below.

1. Maxima is a free open source application running on various operating systems and covers a wide range of mathematical and graphical features.

Payment: Free.

Writing in: Common Lisp.

Operation system: Linux, macOS, Microsoft Windows.

2. Sage Math is a system for experiments in algebra and geometry that covers many aspects of mathematics.

Payment: Free.

Written in: Python, Cython.

Platforms: Linux, macOS, Microsoft Windows, Solaris, Android, IOS.

3. Wolfram Mathematics is a system that is characterized by technical perfection and elegant ease of use, contains many functions for analytical transformations and allows you to work with graphics and sound.

Payment: Requires payment.

Written in: C, C++, Java, Wolfram language.

Operation system: Linux, macOS, Microsoft Windows.

4. Maple is a system that has 5000 functions for mathematics, modeling, interactive visualization and its own programming language.

Payment: Requires payment.

Written in: Simple language.

Operation system: Linux, macOS, Microsoft Windows.

5. SymPy is a Python library for symbolic mathematics.

Payment: Requires payment.

Written in: Python.

Operating system: Cross-platform.

6. GNU Octave is a system of mathematical calculations that is compatible with MATLAB and can be used to solve equations, calculate with complex number, visualize data and conduct the experiments.

Payment: Free

Programming language: C++

Operating system: GNU/Linux, UNIX, Cygwin

7. MathStudio is the most powerful online computing software available for Chrome, which surpasses Wolfram Alpha in terms of speed and quality of results.

Payment: Free.

Written in: Python.

[10] What are the best computer algebra systems? URL: https://www.slant.co/topics/6177/~computer-algebra-systems

Operating system: IOS, Android.

8. PTC MathCAD is an automated design system that is focused on the preparation of interactive documents with calculations and visual accompaniment. Some features of this system are based on a subset of the CAS Maple or use the MuPAD kernel. MathCAD is convenient to use for learning, computing and engineering calculations.

Payment: Free.

Written in: C++, C#, VB, VBScript and JavaScript.

Operating system: Windows.

9. GeoGebra CAS Calculator is a dynamic geometric environment that allows you to create drawings for solving problems of algebra, geometry, and also provides opportunities for computing, operations with functions using built-in language.

Payment: Free.

Written in: JavaScript, HTML5

Operating system: Windows, Linux, IOS, macOS, Google Chrome OS, Android.

10. Magma is a large software package designed for computing in those areas of mathematics that relate to algebra.

Payment: Free.

Written in: C (kernel), Magma (libraries).

Operating system: Cross platform.

11. Math Handbook is a calculator, which has the function of AI machine learning. It is unique for solving differential equations of any order. This CAS allows users to solve problems with real and complex unknowns.

Payment: Free.

Written in: Java.

Operating system: Windows, IOS, Android.

12. Engineering Paper.xyz is a free open source web application that is an alternative to MathCAD for engineering calculations.

Payment: Free.

Written in: Python.

Operating system: Windows, Linux, macOS, Chrome OS, IOS, Android.

Analyzing the CAS presented in the list, it is necessary to note their attractiveness for use in the educational process due to the wide possibilities and availability of use. At the same time, the question is: what principles should we use for selecting a package of CAS programs? Given the amount of mathematical knowledge necessary for education, the choice can be made collegially by teachers of an educational institution or individually by the educational applicant, provided that there are no proposals from the relevant university.

In the case of existing software in the educational institution, educational applicants get free access to use it. All users have real and virtual assistants to get acquainted with the basic functions, libraries and features of the CAS interface.

In higher technical institutions of Ukraine, the most popular CAS are Mathematica, MathLab, MathCAD and Maple, that are also effectively used in educational institutions of the USA, Canada, Europe, Japan, China, etc. These systems have a user-friendly interface, implement many standard and special mathematical functions, have powerful graphics tools, own programming languages, allow you to import data into other software products and allow the return export of information[11]. But when you choose any of the four listed CAS you should take into account their advantages and disadvantages[12]. The general list of pros and cons CAS named is presented in Table 2.1.

According to the presented comparative analysis of the characteristics of CAS, Maple software is the most convenient tool for using in the educational process. Indeed, the advantages of Maple are significant in comparison with other CAS presented in Table 2.1, and the existing disadvantages have little effect on both teaching and learning mathematics.

The best way to evaluate the capabilities of CAS Maple is to visit the official page of Maplesoft: Math Education[13] that opens up ways for comprehensive development with multilevel assistance in the study of mathematics. The CAS Maple platform combines mathematical technologies and expertise with data analytics and AI methods to help educational applicants succeed in completing independent work tasks.

[11] Музика Л. Використання систем комп'ютерної математики на прикладі Wolfram Alpha при вивченні вищої математики. *Молодь і ринок*. № 8 (127). Дрогобич. 2015. С. 104–107. https://core.ac.uk/download/pdf/326327426.pdf

[12] Россоха І.В., Рендюк С.П. Використання систем комп'ютерної математики в вищій освіті. *74-а наукова конференція професорів, викладачів, наукових працівників, аспірантів та студентів НУПП ім. Юрія Кондратюка*: матеріали 74-ї наукової конференції НУПП ім. Юрія Кондратюка (Полтава, 25 квітня – 21 травня 2022). Т1. Полтава. 2022. С. 205–206. https://reposit.nupp.edu.ua/bitstream/PoltNTU/11071/1/74-та%20конф%20Т.1-205-206.pdf#:~:text=У%20вищих%20технічних%20закладах%20вищої%20освіти%20України%20у,математики%20є%3A%20Mathematica%2C%20Mathcad%2C%20Maple%2C%20Matlab%2C%20R%2C%20Derive

[13] Software Solutions for Math Education. URL: https://maplesoft.com/products/maple/math-suite-education/

Table 2.1

General characteristics of CAS

Name CAS	Advantages	Disadvantages
Mathematica	– support for parallel computing – statistical analysis of models – unique 3D graphics – compatible with different – operating platforms – the graphical interface allows you to work with many documents – high speed calculations	– difficult syntax – excessive protection from copying – focus on experienced users
MathLab	– unique matrix means – descriptive graphics – high speed calculations – adaptation to user tasks and multiplicity of system expansion packages – compatible with different operating platforms	– limited possibilities of symbolic calculations – the jewel of the system and its expansion packs – lack of support in the kernel for solving inequalities, recurrent relations
MathCAD	– simple clear interface – the presence of editors of formulas, text and graph-analytical objects – supports symbolic and numerical calculations – operations with matrices and vectors high-quality graphics – supports integration with other programs	– lack of graphical interface – inability to make changes to the structure of the document – only available to users in the educational or engineering fields of activity – difficulties in installing and configuring the program
Maple	– the thought-out kernel of symbolic calculations – high-quality graphics – convenient assistance system – high accuracy of calculations intuitive interface – supports working with databases	– lack of synthesis of sounds – inconvenience in working with a large number of data

3. The use of CAS on the example of Maple in teaching and learning higher mathematics

In the context of informatization and humanization of the education system in Ukraine, it is important to find ways to promote the fundamental mathematical knowledge In this case the choice of CAS should be based on the needs for mathematical training of students that exist in the educational institution.

The issue of using Maple in the academic activities of educational institutions in Ukraine has remained relevant for the past twenty years. Some Ukrainian universities already have some experience in implementing Maple mathematical software in the educational process. That experience demonstrates the need to create appropriate methods for using the high-tech CAS Maple package in education.

The paper[14] highlights the results of the development and implementation of a training complex in higher mathematics, including a task generator and a simulator that reproduces the entire process of solving typical mathematical problems, in the educational process of Vinnitsa National Technical University (VNTU). Simulator procedures created in the Maple environment help to increase the effectiveness of training. On the one hand, they allow the educational applicants to work independently and check the correctness of the solutions obtained. On the other hand, such simulators optimize the teacher's work by reducing the time spent on checking independent work performed by students.

The issue of creating generators of simulator programs in the Maple environment is separately considered in the paper[15] and related publications of that author. The constructed models, algorithms and programs were tested on examples of generating problems from various sections of higher mathematics taught at VNTU.

The continuation of a series of publications related to the implementation of CAS Maple in the educational process of VNTU is the work on the creation of simulator programs for finding the extrema of a function of two variables[16]. When creating the program, the standard procedure for finding the minimum of a function of two variables, which is built into the CAS Maple, is taken as a basis. According to the results on the effectiveness of using CAS in education, it was found that the use of Maple tools improves the level of knowledge of educational applicants.

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[14] Михалевич В.М., Крупський Я.В. *Інформаційні технології і засоби навчання*. № 1(21). Вінниця, 2011. С. 1–23. URL: https://ir.lib.vntu.edu.ua/handle/123456789/13927?show=full

[15] Михалевич В.М. Методика створення генераторів завдань з математики. *Сучасні інформаційні технології та інноваційні методики навчання у підготовці фахівців: методологія, теорія, досвід, проблеми*: збірник наукових праць. Вип. 16. Київ–Вінниця, 2008. С. 416–420. URL: https://ir.lib.vntu.edu.ua/handle/123456789/24973?show=full

[16] Krupskyi Y., Tiytiynnyk O., Klieopa I. (2020) Educational maple-simulator functions of two variables as a means of activation of independent work of students in the conditions of distance learning. Modern Information Technologies and Innovation Methodologies of Education in Professional Training Methodology Theory Experience Problems. P. 20–28. URL: https://doi.org/10.31652/2412-1142-2021-61-20-28

The experience of using CAS Maple in the educational process outside Ukraine also shows that it was not actively used in academic activities until 2019. This is probably related to the focus of the first developments, which had to cover the needs of trained users involved in research projects. It was only after the III and IV International Conferences «Maple in Mathematics Education and Research» CAS Maple was called an ideal tool for both education and research. The reports of the experts published in the conference proceedings[17].[18] demonstrate the possibilities of using Maple in education, namely, the applied aspects of Maplesoft, as well as the visualization of the process and results of calculations by introducing interactive functions that improve the understanding of theoretical issues.

The positive experience of using the Maple SCS in the educational process is also evidenced by the results of a study conducted in the Bachelor's and Master's degree programs in biotechnology at the University of Turin (Italy)[19]. The above-mentioned educational applicants used Maple tools throughout the entire period of study. Then, when they defended their graduation theses, it was noted that the projects prepared by the bio-technology students had a higher scientific level compared to the scientific works of other graduates.

Another positive example is the result of a research that was conducted at the Khairun University (Indonesia)[20]. The purpose of this study was to investigate the impact of using Maple tools on the level of mastering the Calculus course by first-year students of the Teacher Education Faculty. The results of the experiment revealed that, compared to previous years, the level of students' practical skills has increased, and this in turn has improved the theoretical knowledge quality of the course topics This experience suggests that similar practices of teaching with Maple can be an alternative model of the educational process aimed at learning not only Calculus, but any mathematical course.

[17] Maple in Mathematics Education and Research: Third Maple Conference, MC 2019. URL:https://books.google.com.ua/books?id=GGXTDwAAQBAJ&printsec=frontcover&hl=uk&source=gbs_ge_summary_r&cad=0#v=onepage&q&f=false

[18] Maple in Mathematics Education and Research: 4th Maple Conference, MC 2020. URL: https://books.google.com.ua/books?id=gkw5EAAAQBAJ&printsec=frontcover&hl=uk&source=gbs_ge_summary_r&cad=0#v=onepage&q&f=false

[19] Fissore C., Marchisio M., Roman F., Sacchet M. (2021) Development of Problem Solving Skills with Maple in Higher Education. Maple in Mathematics Education and Research. MC 2020. Communications in Computer and Information Science. Vol. 1414. URL: https://doi.org/10.1007/978-3-030-81698-8_15

[20] Hamid H., Angkotasan N., Jalal A., Muhtadi D., Sukirwan (2020) Students' mathematical proficiency in solving calculus problems after Maple implementation. J. Phys.: Conf. Ser. Vol. 1613. URL: https://iopscience.iop.org/article/10.1088/1742-6596/1613/1/012025/pdf

Given the positive outlook for the use of Maple tools in the educational process, it is necessary to develop a concept for integrating CAS Maple into academic activities that will meet the needs of both teachers and students.

One of the ways to motivate students to study higher mathematics is to take into account their specifics of education. Indeed, there will always be applied professional tasks that can be solved by mathematical methods. These are the kinds of tasks that should be considered in class together with the teacher. Applied problems, firstly, best demonstrate to educational applicants the connection between the educational components taught, and secondly, indicate the level of theoretical knowledge and skills required to solve a particular problem. At the same time, the use of Maple tools should accompany the entire solution process: from building a mathematical model to obtaining a solution.

Technologically, the process of solving an application problem can be reproduced in the Maple environment using a specific algorithm and built-in commands and functions. But for correcting the initial data and/or modeling critical situations, the best tool is to create maplets that allow the user to experiment, change parameters, and observe the modeled object in real time.

The experience of creating maplets in the Maple environment and their implementation in the educational process in Ukraine is quite extensive and is associated with the publications of many authors. In addition to the online help and guidelines for creating maplets, which can be found on the Maplesoft website[21], there are similar helpers with explanations and step-by-step instructions that are posted on student websites[22].

When programming in the Maple environment, you need to know the built-in language, be able to use the Maplets package tools, and understand the algorithm of actions For example, in paper[23] the maplet was created that allows solving quadratic equations and visualizing the results of the solution The value of this work is the fact that the entire process of creating a maplet algorithm is accompanied by detailed instructions that can help a Maple user create an application to solve a similar problem. Another example is the page of Texas, A&M University of S. Carolina[24] that contains a collection

[21] Maplets tutorial. URL: https://www.maplesoft.com/support/help/Maple/view.aspx?path=examples/MapletsTutorial

[22] Пакети Maplets. URL: https://studwood.net/1755692/informatika/paketi_maplets

[23] Нарадовий В. Використання маплетів у викладацькій діяльності та науково-дослідній роботі. Наукові записки. Серія: *Проблеми природничо-математичної, технологічної та професійної освіти.* Вип. 1(3). Кропивницький, 2023. С. 16–21. URL: https://doi.org/10.32782/cusu-pmtp-2023-1-2

[24] Maplets for Calculus. URL: https://calclab.math.tamu.edu/maple/maplets/contents.html

of maplets developed for the Calculus course, which allow solving typical problems of mathematical analysis and, thanks to visualization and animation, improve understanding of the course's theoretical aspects. At the same time, only some of the presented maplets are available for use when visiting the specified page. But even a visual overview of the maplets database helps to comprehend the huge amount of work that has been done by university teachers to ensure the appropriate level of use of the latest intellectual technologies in the educational process.

Thus, as part of the innovative changes that are taking place in all types of activities, it is necessary to develop practical cases that will improve not only the format of the educational process in Ukraine, but also the quality of education.

When teaching higher mathematics to educational applicants with a non-mathematical education, the focus should be on the applied character of mathematical knowledge. For example, when studying the elements of linear algebra by students of technical universities, you can offer to solve an applied electrical engineering problem using Maple tools.

Problem 3.1. On the basis of Kirchhoff's laws, draw up a system of linear algebraic equations that describes the distribution of currents in an electrical circuit (Fig. 3.1) and determine the current strength.

The known resistances and sources of electromotive forces (EMF) correspond to the values given in Table 3.1.

The circuit shown in Fig. 3.1 contains six branches, each of which contains a source of constant EMF and a resistor. To calculate an electric circuit using the Kirchhoff method, you need to:

1) randomly select the expected directions of currents in all *n* branches;

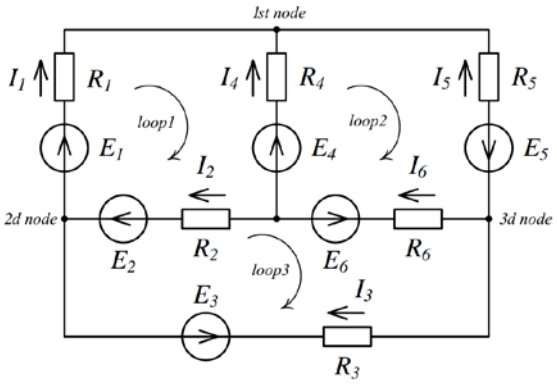


Fig. 3.1. Diagram of a steady-state current circuit

Table 3.1

Numerical parameters of an electric circuit

Resistances *(Ohms)*	*R1*	*R2*	*R3*	*R4*	*R5*	*R6*
	12	21	19	16	29	14
EMF sources (*Volts)*	*E1*	*E2*	*E3*	*E4*	*E5*	*E6*
	81	15	44	17	25	15

2) determine the number m of independent circuits and select the traversal directions in them;

3) for a circle containing k nodes, using Kirchhoff's first law, get independent equations for k-1 nodes;

4) according to Kirchhoff's second law, write a system of m independent equations for each circuit;

5) solve the resulting system containing n=m+k-1 linear algebraic equations and n unknowns;

6) if negative currents are obtained, conclude that the directions of these currents are opposite to those shown in the diagram.

Provided that requirements 1)-5) are met, the system of equations obtained for k=4, m=3, n=6 is as follows:

$$\begin{cases} I_1 + I_4 + I_5 = 0; \\ -I_1 + I_2 + I_3 = 0; \\ -I_3 - I_5 - I_6 = 0; \\ I_1R_1 + I_2R_2 - I_4R_4 = E_1 + E_2 - E_4; \\ I_4R_4 - I_5R_5 + I_6R_6 = E_4 + E_5 - E_6; \\ -I_2R_2 + I_3R_3 - I_6R_6 = -E_2 - E_3 + E_6; \end{cases} \tag{3.1}$$

where I_l – currents, R_l – resistances, E_l – EMF sources in the branch l (l=1..6).

This system (3.1) is written in matrix form as follows:

$$\begin{pmatrix} 1 & 0 & 0 & 1 & 1 & 0 \\ -1 & 1 & 1 & 0 & 0 & 0 \\ 0 & 0 & -1 & 0 & -1 & -1 \\ R_1 & R_2 & 0 & -R_4 & 0 & 0 \\ 0 & 0 & 0 & R_4 & -R_5 & R_6 \\ 0 & -R_2 & R_3 & 0 & 0 & -R_6 \end{pmatrix} \begin{pmatrix} I_1 \\ I_2 \\ I_3 \\ I_4 \\ I_5 \\ I_6 \end{pmatrix} = \begin{pmatrix} 0 \\ 0 \\ 0 \\ E_1 + E_2 - E_4 \\ E_4 + E_5 - E_6 \\ -E_2 - E_3 + E_6 \end{pmatrix} \tag{3.2}$$

or

$$R \cdot I = E, \tag{3.3}$$

where R is the matrix of resistances, I is the matrix of currents, E is the matrix of loop EMFs.

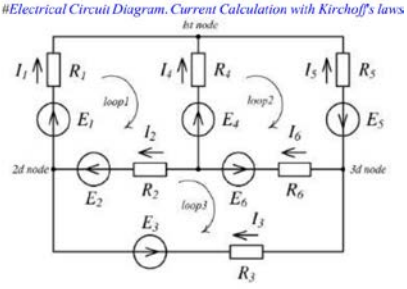
The solution of the matrix equation (3.3) is the matrix I, which can be found by the formula:

$$I = R^{-1} \cdot E, \tag{3.4}$$

where R^{-1} is the inverse of the matrix R.

The order of the matrix R is six, so it is advisable to solve the problem using the CAS. To do this, in the Maple environment, you can save the task in the form of a figure:

```
> restart :
> #Electrical Circuit Diagram. Current Calculation with Kirchoff's laws
```



To solve the problem, it is convenient to use the *Linear Algebra* package, which allows you to work with matrices, determinants and find solutions to systems of linear algebraic equations.

```
> with(LinearAlgebra) :#Solving Matrix Equation  AX=B
> #Enter dataset
> R1 := 12 :R2 := 21 :R3 := 19 :R4 := 16 :R5 := 29 :R6 := 14 :
  E1 := 81 :E2 := 15 :E3 := 44 :E4 := 17 :E5 := 25 :E6 := 15 :
```

$$> A := \begin{bmatrix} 1 & 0 & 0 & 1 & 1 & 0 \\ -1 & 1 & 1 & 0 & 0 & 0 \\ 0 & 0 & -1 & 0 & -1 & -1 \\ R_1 & R_2 & 0 & -R_4 & 0 & 0 \\ 0 & 0 & 0 & R_4 & -R_5 & R_6 \\ 0 & -R_2 & R_3 & 0 & 0 & -R_6 \end{bmatrix} : B := \begin{bmatrix} 0 \\ 0 \\ 0 \\ E_1 + E_2 - E_4 \\ E_4 + E_5 - E_6 \\ -E_2 - E_3 + E_6 \end{bmatrix} :$$

Then, to check the compatibility of the system of equations written in matrix form *AX=B*, it is necessary to find the determinant of the main matrix *A* of the coefficients of the system, whose elements are numbers and unknowns. To work correctly with such objects in the *LinearAlgebra* package, when executing the *Determinant*(*A*,*m*) command, you must specify the second argument: *method = multivar*, which allows you to get the value of the determinant containing both numeric elements and symbolic ones.

```
> detA := Determinant(A, method = multivar)
                                  detA := 97259
```
(1)

If the problem is correctly formulated, the system *AX=B* has a unique solution.

A compatible system of equations is definite if the matrix *A* is not singular. Then the solution of the system is the vector *X*, whose coordinates correspond to the values of the currents in Fig. 3.1.

```
> #checking the singularity of matrix A
> if detA ≠ 0 then X := evalf(LinearSolve(A, B))
  else print('Matrix A is singular. Check dataset')

  end if
```

$$X := \begin{bmatrix} 2.088 \\ 1.808 \\ 0.280 \\ -0.998 \\ -1.090 \\ 0.810 \end{bmatrix} \quad (1)$$

The obtained solution contains negative components, which means the following: the directions of currents I_4, I_5 in the corresponding branches are opposite to those predicted in Fig. 3.1

The proposed method of solving the problem is quite simple in terms of working with matrices and systems of high order. However, working with CAS tools develops algorithmic thinking skills. The task has to be divided into smaller ones: it is necessary to analyze the circuit diagram, compose the corresponding system of linear algebraic equations, check it for compatibility and solve it using the built-in commands of the *LinearAlgebra* package. The proposed algorithm can be used to solve a similar problem with other input data. Therefore, its application can be useful for both educational applicants and teachers.

Alternative way to solve Problem 3.1 is to create a maplet in the Maple environment. Before starting work, you may save the diagram image (Fig. 3.1) in the format **Figure.jpg** in the root directory on drive D. Then, using

the maplet builder tools, the path to which is **Tools→Assistants→Maplet Builder** on the active Maple page, create a template. For detailed instructions on the steps involved in building a maplet layout, see the Maplets Tutorial page of Maplesoft. The template structure can have a design like the one shown in Fig. 3.2 or another one.

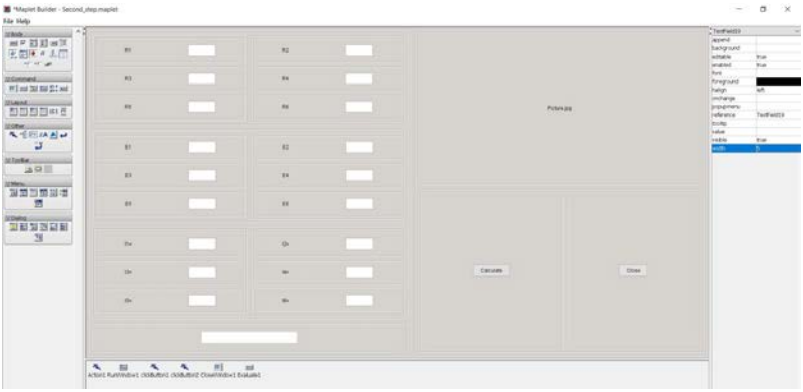


Fig. 3.2. An exemplary layout of a maplet window

The created template is saved in the **Project.maplet** file and opened on the active Maple page. The opened file contains the program code of the built maplet template, which needs to be improved. According to the template in Fig. 3.2, it is necessary to make changes to the existing code that is associated with:

– renaming the **Window** element to **Current:**

```
>            BoxColumn(
>                  BoxRow(
>                        BoxCell('hscroll'='never','value'='Label19','vscroll'='never')),
>                  BoxRow(
>                        BoxColumn(
>                              BoxCell('hscroll'='never','value'='Button1','vscroll'='never')),
>                        BoxColumn(
>                              BoxCell('hscroll'='never','value'='Button2','vscroll'='never'))))),
>      Window('layout'='BoxLayout1','reference'='Window1','resizable'='true','title'="Current"),
>      Action('reference'='Action1',
>            RunWindow('window'='Window1'))):
>
> Maplets[Display](maplet);
>
```

– adding elements of the **Comments** text panel:

```
>                  BoxRow('caption'="Comments",'border'='true',
>                        BoxCell('hscroll'='never','value'='TextBox1','vscroll'='never'))),
>            BoxColumn(
>                  BoxRow(
>                        BoxCell('hscroll'='never','value'='Label19','vscroll'='never')),
>                  BoxRow(
>                        BoxColumn(
>                              BoxCell('hscroll'='never','value'='Button1','vscroll'='never')),
>                        BoxColumn(
>                              BoxCell('hscroll'='never','value'='Button2','vscroll'='never'))))),
```

– adding a header to the row containing the required current values:

```
>                 BoxRow('caption'="Current Forces",'border'='true',
>                       BoxColumn(
>                             BoxRow(
>                                   BoxCell('hscroll'='never','value'='Label13','vscroll'='never'),
>                                   BoxCell('hscroll'='never','value'='TextField14','vscroll'='never')),
>                             BoxRow(
>                                   BoxCell('hscroll'='never','value'='Label14','vscroll'='never'),
>                                   BoxCell('hscroll'='never','value'='TextField15','vscroll'='never')),
>                             BoxRow(
>                                   BoxCell('hscroll'='never','value'='Label15','vscroll'='never'),
>                                   BoxCell('hscroll'='never','value'='TextField16','vscroll'='never'))),
>                       BoxColumn(
>                             BoxRow(
>                                   BoxCell('hscroll'='never','value'='Label16','vscroll'='never'),
>                                   BoxCell('hscroll'='never','value'='TextField17','vscroll'='never')),
>                             BoxRow(
>                                   BoxCell('hscroll'='never','value'='Label17','vscroll'='never'),
>                                   BoxCell('hscroll'='never','value'='TextField18','vscroll'='never')),
>                             BoxRow(
>                                   BoxCell('hscroll'='never','value'='Label18','vscroll'='never'),
>                                   BoxCell('hscroll'='never','value'='TextField19','vscroll'='never')))),
>                 BoxRow('caption'="Comments",'border'='true',
```

– adding a header to the row containing the known EMF values:

```
>                 BoxRow('caption'="Electromotive Forces",'border'='true',
>                       BoxColumn(
>                             BoxRow(
>                                   BoxCell('hscroll'='never','value'='Label7','vscroll'='never'),
>                                   BoxCell('hscroll'='never','value'='TextField7','vscroll'='never')),
>                             BoxRow(
>                                   BoxCell('hscroll'='never','value'='Label8','vscroll'='never'),
>                                   BoxCell('hscroll'='never','value'='TextField8','vscroll'='never')),
>                             BoxRow(
>                                   BoxCell('hscroll'='never','value'='Label21','vscroll'='never'),
>                                   BoxCell('hscroll'='never','value'='TextField10','vscroll'='never'))),
>                       BoxColumn(
>                             BoxRow(
>                                   BoxCell('hscroll'='never','value'='Label10','vscroll'='never'),
>                                   BoxCell('hscroll'='never','value'='TextField11','vscroll'='never')),
>                             BoxRow(
>                                   BoxCell('hscroll'='never','value'='Label11','vscroll'='never'),
>                                   BoxCell('hscroll'='never','value'='TextField12','vscroll'='never')),
>                             BoxRow(
>                                   BoxCell('hscroll'='never','value'='Label12','vscroll'='never'),
>                                   BoxCell('hscroll'='never','value'='TextField13','vscroll'='never')))),
>                 BoxRow('caption'="Current Forces",'border'='true',
```

– adding a header to the row containing the known resistance values:

```
>                  BoxRow('caption'="Resistances",'border'='true',
>                        BoxColumn(
>                              BoxRow(
>                                    BoxCell('hscroll'='never','value'='Label1','vscroll'='never'),
>                                    BoxCell('hscroll'='never','value'='TextField1','vscroll'='never')),
>                              BoxRow(
>                                    BoxCell('hscroll'='never','value'='Label3','vscroll'='never'),
>                                    BoxCell('hscroll'='never','value'='TextField2','vscroll'='never')),
>                              BoxRow(
>                                    BoxCell('hscroll'='never','value'='Label4','vscroll'='never'),
>                                    BoxCell('hscroll'='never','value'='TextField3','vscroll'='never'))),
>                        BoxColumn(
>                              BoxRow(
>                                    BoxCell('hscroll'='never','value'='Label2','vscroll'='never'),
>                                    BoxCell('hscroll'='never','value'='TextField4','vscroll'='never')),
>                              BoxRow(
>                                    BoxCell('hscroll'='never','value'='Label5','vscroll'='never'),
>                                    BoxCell('hscroll'='never','value'='TextField5','vscroll'='never')),
>                              BoxRow(
>                                    BoxCell('hscroll'='never','value'='Label6','vscroll'='never'),
>                                    BoxCell('hscroll'='never','value'='TextField6','vscroll'='never')))),
>                  BoxRow('caption'="Electromotive Forces",'border'='true',
```

– adding Fig. 3.1 to the maplet:

```
>       Label('background'="$D6D3CE",'caption'="",Image("D:El_Circuit_1.jpg"),'enabled'='true','foreground'="$000000",'reference'=
  'Label19','visible'='true'),
```

– adding the body of the procedure for calculating the electrical circuit shown in Fig. 3.1 by means of matrix calculus:

```
> restart:
  with(LinearAlgebra):
  Digits:=4:

  with (Maplets[Elements]):
  myproc:=proc()
  local R1,R2,R3,R4,R5,R6,E1,E2,E3,E4,E5,E6,A,B,X,N,DD:

  R1:=Maplets[Tools][Get]('TextField1'::algebraic,corrections):
  R2:=Maplets[Tools][Get]('TextField4'::algebraic,corrections):
  R3:=Maplets[Tools][Get]('TextField2'::algebraic,corrections):
  R4:=Maplets[Tools][Get]('TextField5'::algebraic,corrections):
  R5:=Maplets[Tools][Get]('TextField3'::algebraic,corrections):
  R6:=Maplets[Tools][Get]('TextField6'::algebraic,corrections):

  E1:=Maplets[Tools][Get]('TextField7'::algebraic,corrections):
  E2:=Maplets[Tools][Get]('TextField11'::algebraic,corrections):
  E3:=Maplets[Tools][Get]('TextField8'::algebraic,corrections):
  E4:=Maplets[Tools][Get]('TextField12'::algebraic,corrections):
  E5:=Maplets[Tools][Get]('TextField10'::algebraic,corrections):
  E6:=Maplets[Tools][Get]('TextField13'::algebraic,corrections):

  N:=6:
  A:=Matrix(N,N,0):
  A[1,1]:=1:A[1,4]:=1:A[1,5]:=1:
  A[2,1]:=-1:A[2,2]:=1:A[2,3]:=1:
  A[3,3]:=-1:A[3,5]:=-1:A[3,6]:=-1:
  A[4,1]:=R1:A[4,2]:=R2:A[4,4]:=-R4:
  A[5,4]:=R4:A[5,5]:=-R5:A[5,6]:=R6:
  A[6,2]:=-R2:A[6,3]:=R3:A[6,6]:=-R6:

  B:=Vector(N,[0,0,0,E1+E2-E4,E4+E5-E6,-E2-E3+E6]):
  DD:=Determinant(A,method=multivar);

  if DD<>0 then X:=LinearSolve(A,B):X:=evalf(X):
  Maplets[Tools][Set]('TextBox1'="Good job!"):
  Maplets[Tools][Set]('TextField14'=X[1]):
  Maplets[Tools][Set]('TextField17'=X[2]):
  Maplets[Tools][Set]('TextField15'=X[3]):
  Maplets[Tools][Set]('TextField18'=X[4]):
  Maplets[Tools][Set]('TextField16'=X[5]):
  Maplets[Tools][Set]('TextField19'=X[6]):

  else
  Maplets[Tools][Set]('TextBox1'="Matrix A is singular!Check dataset"):
  end if:

  end proc:

> maplet :=
> Maplet('onstartup'='Action1','reference'='Maplet1',
```

– setting the **Calculate** button.

```
>           Evaluate('function'='myproc','option'="value",'waitforresult'='true')')
>     Action('reference'='ClickButton1',
 'Label1','visible'='true')'
>     Label('background'="#DEDBCE",'caption'="",'image'="C:/Fig_Circuit_1.jpg")','enabled'='true','foreground'="#000000",'reference'=
```

In the **Evaluate** line, add the name of the **myproc** procedure and remove the link to the object ‘target’=‘ TextBox1’.

After running the ready-to-use maplet procedure, the template opens, in which you need to enter the known values of resistances and EMF and click the **Calculate** button. Then the result of the maplet will look like in Fig. 3.3.

Analysis of the obtained **Current Forces** solutions shows that they correspond to the results that are components of the X matrix. The differences in the number of decimal places in the obtained values of current forces are related to the use of the *Digits*:=4 command in the body of the maplet procedure.

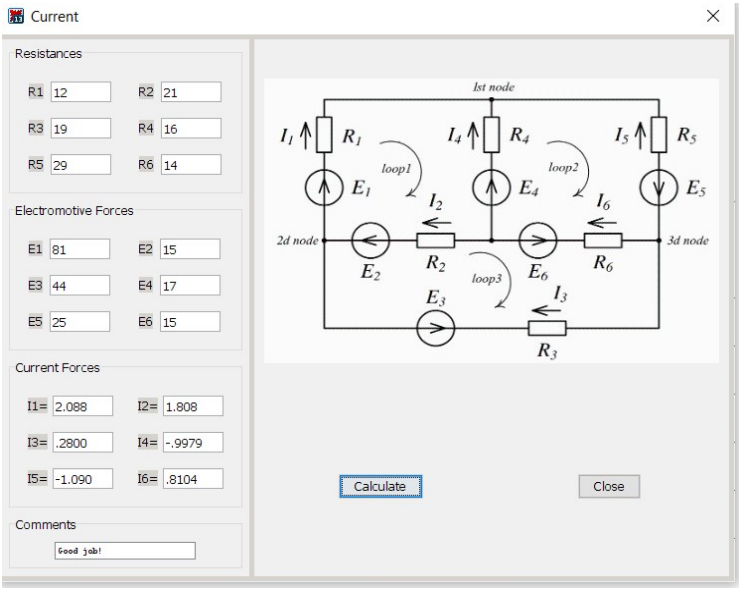


Fig. 3.3. The Current maplet interface

It is obvious that the calculation of a direct current circuit according to the diagram in Fig.3.1 by creating a maplet in the Maple environment requires users to know not only the elements of electrical engineering and matrix calculus, but also the basics of programming. Therefore, solving problems in this way can only be offered to trained teachers. At the same time, well-established maplet procedures allow you to experiment with problem data, draw summarized conclusions and identify individual cases that develops the critical thinking abilities. For teachers, the use of maplets in the educational process not only improves their skills in algorithmization the processes of solving mathematical and applied problems, but also optimizes the time required to test solutions to typical problems. At that, proficiency in the programming language and Maple tools helps in performing computational experiments in any scientific research, which is an integral part of the scientific and pedagogical work of academic staff.

CONCLUSIONS

Based on the results of the study on the integration of intelligent technologies into the educational process, a rating list of AI-based applications and platforms and CASs offered in the information space was created based on the advantages in accessibility, defined limits of application and accuracy of mathematical problem solving. The main criterion for

choosing intelligent technologies to be implemented in academic activities in teaching and learning higher mathematics is to improve the quality of mathematical education in Ukrainian universities.

In order to prevent situations that could be interpreted as academic dishonesty, the experience of implementing AI technologies in education is studied on the basis of internal documents of the Igor Sikorsky Kyiv Polytechnic Institute and the University of South Carolina, USA.

To solve the problem of improving the quality of mathematical knowledge, the case technology is applied, which consists in the development of computational thinking skills based on the ability to divide the problem into parts and can be used to create software codes in the CAS environment. Maple software was chosen among the most widely used in Ukraine and abroad, as it allows users to experiment, model critical situations and work in a dialogue mode.

In the context of digitalization of education, a practical case is proposed: when teaching and learning higher mathematics, to solve applied problems using mathematical methods that can be generated in Maple. The example of calculating an electric circuit with Maple tools shows the applied nature of mathematical knowledge and demonstrates the advantages of algorithmic solution in real time, which creates positive preconditions for the development of a highly effective educational package of methods for solving mathematical and applied problems in the CAS Maple environment.

SUMMARY

Given the rapid development of intelligent technologies, the issue of their impact on the quality of education is becoming increasingly relevant. This, in turn, creates a demand for the development of rules for the use of AI-based technologies and tools for their implementation in the academic activities of educational institutions. To determine the conditions for the use of intelligent technologies in teaching and learning higher mathematics, the advantages and disadvantages of AI-based applications and platforms offered in the information space and intended for solving mathematical problems are investigated. The study revealed an insufficient level of the problems they solve and an alternative model of introducing the latest technologies, namely, the Maple computer algebra system, which is recognized as the most powerful among the best in the world, was chosen.

To improve the mathematical knowledge level in Ukrainian educational institutions, a practical case is proposed, which consists in solving applied professional problems using mathematical methods in the environment of the Maple computer algebra system. The main advantage of this approach to teaching and learning higher mathematics is the identification of branches of mathematical knowledge that are used to model objects of different nature.

The proposed problem of calculating a steady-state electric circuit, solved with the use of Maple tools, demonstrates the possibilities of algorithmic process of solving the problem using two methods and indicates the direction of further research.

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