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VISUALIZATION OF PHYSICAL PROCESSES AS A MEANS OF DEVELOPING PROFESSIONAL COMPETENCIES AMONG STUDENTS MAJORING IN COMPUTER AND SOFTWARE ENGINEERING (ON THE EXAMPLE OF THE JOULE–LENZ LAW)

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Abstract

This article examines a pedagogical approach based on the collaborative creation of infographics on the topic of the Joule–Lenz law by teachers and students. The study was conducted with students majoring in Computer Engineering and Software Engineering. It is demonstrated that the principle of visualization can be effectively implemented through the digital representation of physical processes and phenomena in higher education. Particular attention is paid to the role of infographics as a tool for developing the professional competencies of future IT specialists. Involving students in the graphical modeling of physical laws through modern digital technologies and artificial intelligence tools contributes to a deeper understanding of educational material, the development of engineering thinking, information analysis skills, and project-based learning competencies. As a result of the collaborative work between teachers and students, six original infographics were created, each reflecting a specific aspect of the Joule–Lenz law, including the physical nature of the phenomenon, practical applications, electrical circuits, household devices, and engineering risks. The findings indicate that this form of work increases students' motivation to study physics, strengthens interdisciplinary connections, and allows physics to be perceived as an important component of the professional training of future engineers.

The scientific novelty of the study lies in integrating physical content, digital visualization, and artificial intelligence technologies into a unified educational process aimed at developing the professional competencies of students in engineering and IT-related fields. The practical significance of the study is determined by the possibility of applying the proposed methodology in teaching physics and related technical disciplines in higher education institutions.

Keywords

physics teaching methodology, educational infographics, Joule–Lenz law, data visualization, computer engineering, software engineering, artificial intelligence in education, independent student work.

1. INTRODUCTION: PSYCHOLOGICAL AND PEDAGOGICAL ASPECTS OF VISUALIZATION

Various forms of independent student activity may be used in the process of studying physics, including solving non-standard physics problems, developing reference materials and lesson outlines, constructing crossword puzzles, creating educational models, and designing infographics and other visual materials. This study focuses on the collaborative work of teachers and students in creating physics-related infographics. The principle of visualization in higher education physics teaching is closely connected with the effective development of sustainable professional competencies among students. Creating infographics is not only a means of illustrating educational material but also a complex cognitive process involving the analysis, structuring, selection, and visual presentation of information. Such activity contributes to increased cognitive engagement, the development of critical thinking, and the formation of sustained interest in the subject. For future specialists in computer engineering and software engineering, working on infographics becomes a bridge between abstract physical laws and their practical technical applications. During this process, students learn to search for, analyze, and verify information effectively, use digital tools, work with graphic editors, and apply elements of artificial intelligence. The use of Internet resources and artificial intelligence technologies in creating educational infographics makes it possible to increase both the amount and density of the information presented. It also contributes to the development of competencies required in the modern engineering and IT environment.

2. THE PHYSICAL NATURE OF THE JOULE–LENZ LAW IN THE ENGINEERING CONTEXT

The thermal effect of electric current is one of the most important phenomena studied in school and university physics courses. When electric current passes through a conductor, part of the electrical energy is transformed into the internal energy of the substance, causing the conductor to heat up. From the perspective of microscopic physics, the heating of a conductor is explained by collisions between free electrons and ions in the crystal lattice. As a result of such collisions, the kinetic energy of the directed motion of electrons is transferred to the particles of the substance, leading to an increase in the conductor's temperature.

Quantitatively, this phenomenon is described by the Joule–Lenz law, according to which the amount of heat generated in a conductor is directly proportional to the square of the current, the resistance of the conductor, and the duration of current flow.

Q = I^2 R t

This relationship is of great importance in engineering practice. The Joule–Lenz law is used in the design of heating elements, household electrical appliances, power supply systems, computer equipment, server hardware, and cooling systems. For students majoring in computer and software engineering, it is especially important to understand that heat generation in electrical circuits is directly related to the reliability of electronic devices, the operation of power supply units, microprocessors, servers, and other technical systems. When studying the Joule–Lenz law, particular attention should be paid to different types of conductor connections

In a series circuit, the current is the same in all sections of the circuit; therefore, the greatest amount of heat is generated in the section with the highest resistance (I = const).

In a parallel circuit, the voltage is the same across all sections, while the most intensive heating occurs in the branch with the lowest resistance (U = const).

Understanding these patterns is important for future engineers, as it helps explain the causes of equipment overheating, select materials with the required resistance, and correctly calculate the parameters of electrical circuits.

3. RESEARCH METHODOLOGY AND ANALYSIS OF STUDENT WORK

The study was conducted during the teaching of the Electrodynamics section to students majoring in Computer Engineering and Software Engineering. Five students took part in the collaborative work, acting as co-authors of the article and developers of the infographics.The aim of the study was to identify the pedagogical potential of infographics in studying the Joule–Lenz law and to determine their influence on the development of professional competencies among students majoring in IT-related fields. During the study, students were asked to independently analyze the physical content of the Joule–Lenz law, identify the most important aspects of the topic, and present them visually. The work was carried out in several stages:

- studying theoretical material;
- analyzing existing visual solutions;

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- selecting graphic elements and diagrams;
- creating sketches;
- digital processing and editing;
- discussing and refining the completed materials.

As a result of the collaborative work, six original infographics (Fig. 1-6) were created, each reflecting a particular aspect of the topic under study.

Fig. 2


ЗАКОН ДЖОУЛЯ - ЛЕНЦА
Джоуль Джеймс Прескотт
(1818-1889)
Ленц Эмилий Христианович
(1804-1865)
Q
I
R
КОЛИЧЕСТВО ТЕПЛОТЫ, ВЫДЕЛЯЕМОЕ ПРОВОДНИКОМ С ТОКОМ РАВНО ПРОИЗВЕДЕНИЮ КВАДРАТА СИЛЫ ТОКА СОПРОТИВЛЕНИЯ ПРОВОДНИКА И ВРЕМЕНИ.
$Q = I^2Rt$
Q-КОЛИЧЕСТВО ТЕПЛОТЫ, ВЫДЕЛЯЕМОЕ ЗА ВРЕМЯ T ПРОВОДНИКОМ ПРИ ПРОТЕКАНИИ ПО НЕМУ ЭЛ. ТОКА, ДЖ
I-СИЛА ТОКА, ТЕКУЩЕГО ПО ПРОВОДНИКУ, А
R- СОПРОТИВЛЕНИЕ ПРОВОДНИКА, ОМ
T-ВРЕМЯ, В ТЕЧЕНИЕ КОТОРОГО ПО ПРОВОДНИКУ ТЕЧЕТ ТОК, С
ОСНОВНОЙ ПРИНЦИП ЭЛЕКТРОНАГРЕВАТЕЛЬНЫХ ПРИБОРОВ

Fig. 1


Закон Джоуля- Ленца
Джеймс Прескотт Джоуль
1818-1889
Ленц
Эмилий Христианович
1804-1865
Зависимость количества выделяемого тепла в проводнике от параметров электрического тока.
Чем больше ток и сопротивление, тем сильнее нагревается проводник
Q=I²Rt
Q— количество теплоты (Джоуль, Дж)
I — сила тока (Ампер, А);
R— сопротивление проводника (Ом);
t— время (секунды, с).

Fig. 3

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Fig. 5

Fig. 6

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Fig. 4

The first infographic focused on the historical aspects of the discovery of the Joule–Lenz law and the role of scientists in the development of electrodynamics.

The second infographic included electrical circuits, formulas, and explanations, contributing to the development of skills in reading technical documentation and analyzing electrical circuits.

The third infographic demonstrated the application of the Joule–Lenz law in technology, including fuses, heating elements, electric furnaces, and welding devices.

The fourth infographic focused on mathematical modeling and emphasized the quadratic dependence of heat generation on current strength.

The fifth infographic connected physical theory with household appliances such as hair dryers, electric kettles, irons, and heaters.

The sixth infographic was devoted to engineering risks, including conductor overheating, short circuits, overloads, and equipment protection systems.

The findings of the study showed that creating infographics contributes to a deeper understanding of the physical content of the topic, the formation of stable interdisciplinary connections, and the development of engineering thinking.

Students noted that working on visual materials enabled them to better understand the relationship between physical formulas, electrical circuits, and practical engineering tasks. In addition, their motivation to study physics increased, as did their interest in applying knowledge in future professional activities.

4. THE ROLE OF ARTIFICIAL INTELLIGENCE IN THE PROCESS OF COLLABORATIVE CREATIVITY

One of the important features of this methodology was the use of artificial intelligence tools in the process of developing infographics. At the same time, artificial intelligence was viewed not as a substitute for students' independent work but as an auxiliary tool that expands the possibilities for searching, analyzing, and visually presenting information.Students used neural network-based services to select color schemes, create compositions, search for visual images, clarify English-language terminology, and edit text fragments. In addition, artificial intelligence tools were used to generate individual design elements and preliminary infographic layouts.However, the substantive part of the work remained entirely under the control of teachers and students. Learners independently determined the structure of the material, selected physical models, verified the correctness of formulas, measurement units, and logical relationships between the elements. This approach allowed students to master a new role in the modern engineering environment — the role of an "architect of meanings," where a person does not simply receive ready-made information from a digital system but manages the process of selecting, verifying, and interpreting it. The use of artificial intelligence in educational activities also contributed to the formation of digital literacy, the development of a critical attitude toward automatically generated data, and an understanding of the limitations of modern technologies.

5. DISCUSSION OF RESULTS AND RESEARCH PROSPECTS

The proposed approach demonstrates the high effectiveness of using infographics in the study of physics by students majoring in IT-related fields. Unlike the traditional study of theoretical material, creating infographics requires students to engage in active intellectual activity, including analysis, synthesis, structuring, and visual interpretation of information.This approach is of particular value for students majoring in Computer Engineering and Software Engineering because it helps establish a connection between the fundamental laws of physics and future professional activities.Completing such tasks contributes to the development of project-based skills, teamwork, digital communication, information search and verification abilities. In addition, students acquire the basics of visual design, which may be useful in interface development, engineering documentation, project presentation, and data analysis.

The present work continues a series of studies devoted to the use of infographics in teaching different sections of physics. Previously, a similar approach had been applied to the study of friction force, Coulomb's law, Newton's laws, vector and scalar quantities, and the topic of lenses.The transition from mechanics to electrodynamics confirms the universal character of the proposed methodology and the possibility of adapting it to different topics within the physics curriculum.

In the future, it is planned to create a complete set of infographic materials covering the main sections of physics for students majoring in engineering and IT-related fields. This may contribute to the formation of an integrated educational environment focused on the development of professional competencies, research skills, and engineering thinking.

6. CONCLUSION

The use of infographics in studying the Joule–Lenz law makes the educational process more visual, modern, and professionally oriented.The creation of visual materials by students contributes to a deeper understanding of the physical content of the topic, the formation of interdisciplinary connections, and the development of skills required by future specialists in computer engineering and software engineering.Collaborative work between teachers and students on infographics represents an effective form of project-based learning that meets the requirements of the digital educational environment and modern engineering education.

The scientific novelty of the study lies in the integration of physical content, digital visualization, and artificial intelligence elements into a unified educational process aimed at developing the professional competencies of students majoring in IT-related fields.

The practical significance of the study is determined by the possibility of applying the proposed approach by teachers of physics, computer science, and engineering disciplines in higher education institutions.

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