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PROBLEM LEARNING AND INTERSUBJECT CONNECTIONS AT PHYSICS LEARNING WITH USE OF COMPUTER EXPERIMENT IN TECHNICAL COLLEGE

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The technique of inclusion of computer demonstrations and computer experiment for problem learning, stimulating solution of problem situation has been given. The way of student motivation to mastering new knowledge on intersubject connection between subject studied here and now with disciplines which will be studied later is shown. The fragment of lecture on physics with use of computer experiment and intersubject connection with TOE course with development of problem situations is given.

Each year facilities of computer engineering are used more and more intensively in learning process. Software and methodology are developed for application in different types of studies: lectures, practical and laboratory ones. Two tendencies may be marked recently in development of software for learning process. The first tendency consists in adaptation of existing programs, text editors, mathematical programs and simulation such as program package MS Office, MathCAD, MathLab, ANSYS Multiphysics, Maxwell 3D and similar programs for learning process. Another tendency is the development and application of special training programs of wide range from those controlling the degree of mastering teaching material to multimedia and interactive program complex. Each tendency has its advantages and disadvantages, however, at the final stage, application in learning process the technique of their including in any method of training is required.

The method of training and the way of presentation of studying material is very important: reading the text in trite language, formal style of statement may cause mute protest at once. Student stops thinking as he does not see any necessity in it, torn from practical issues and starts operate only with symbols and numbers. Any use of visual aids is important for students as it allows focusing maximally on object of investigation and in this case «lively» text is explained by simple spoken language; that is why connection of computer experiment with theoretical analysis of the examined phenomena is an organic and actual process. Here one can see the elements of that cognitive cycle which is described by V.G. Razumovskii [1]: «observation – hypothesis – carrying out the experiments – analysis of the results – theoretical generalization – practical application». These elements of cognitive process act in various forms applying different methods of including students in work when solving the problem and arrangement of its computer maintenance for proper analysis. Analysis of intrinsic logic of physical knowledge shows that theory components contact with reality through the system of experimental procedures. The character of theory components connection with reality is rather complex and various. The role of computer maintenance is also different; it arranges certain qualitative and quantitative characteristic of connection and relations of real objects which correspond to these components.

The sense of problem statement, as it is known, consists in understanding logic of solution of various problems which are raised specially by lecturer for students. Computer maintenance may be used at problem statement of teaching material.

Problem situation is the situation of cognitive problem occurring at necessity of solving contradiction between knowledge and ignorance. In scientific literature [1–3] various types of classifications of contradictions being in the basis of occurrence of problem situations may be met. Relying on classification of T.A. Ilyina [4] let us examine three types of contradictions observed when studying physics.

Contradictions between new facts (phenomena) and impossibility of their explanation on the basis of existing knowledge refer to the first of them. To solve such contradictions it is necessary to put forward new positions and models, to develop new theories etc.

The second type of contradictions occurs in cases when new fact may be explained within the studied theory but it requires establishment of new relations between separate characteristics of phenomenon. Solution of such contradictions extends and corrects student knowledge within the model, theory known to them.

The third type of contradictions is formed when there is a necessity to explain the results of observation of known phenomenon in new conditions. In these cases the intelligent problem connected with the necessity of applying known knowledge and actions in unknown conditions (to implement ascension from abstract to concrete) occurs. Computer demonstrations and experiments in this case allow specifying knowledge. Such tests allow penetrating deeper into process essence; give the possibility of estimating differently accompanying phenomena. In the process of such contradictions not only new knowledge is expanded but also new intelligent skills and abilities are formed.

Presence of conflicting data in problem situation causes process of thinking directed to their removal that is activates the process of thinking. Therefore, presentation of vivid suspense problem tasks with clearly defined informative-cognitive contradiction to the students is sensible. Paradoxical form of tasks meets such condition best of all. Students observe unexpected phenomena which seem incredible for them. Such conflict tests at-

tract their attention best of all initiating cognitive interest and independent cognitive search.

Defining such problem situations it is necessary to observe commensurability of audience level of qualification and complexity of the put forward problems as a problem situation may occur only in the case if a student is possible to solve the put forward problem i. e. his intellectual abilities should conform to the level of the problem. Therefore, organizing problem situations of such type it should be taken into account that occurrence of cognitive demand in audience is possible only at serious preliminary training.

Thus, learning with use of computer support requires such organization of lectures at which students obtain skills and knowledge in the process of overcoming difficulties formed by a new form of problem definition. Any situation with use of computer support includes a demand for new knowledge or skill occurring as a result of implementing the task analytically.

For more efficient processing of the perceived information in knowledge the trainee should compare it with known facts, notions, definitions, generalize it and lay into a certain knowledge system in his consciousness. The main thing in high school education is not storage of the obtained information but its comprehension, content understanding, awareness of interaction with previous or known information which resulted in occurrence of skill of finding answers to the questions stated by a professor and life. It requires active creative work of student, ability to analyze the obtained information and find the principle thing. For this purpose the professor should create problem situation more often giving the information. It makes student write down lectures deliberately; taking it consciously. The professor working with specialized audience organizes lecture in the form of a dialogue with students so that each movement of student intellect would be a guess, his small discovery. Development of problem situations, their analysis, active participation of students in search of ways of solutions of assigned educational task excite cognitive activity and support deep cognitive interest. Didacts note that professor questions on lecture have almost primary value in activation of student cognitive activity; the trainee should examine new phenomenon himself during the lecture. But *it is not always possible to implement problem learning in practice. Use of multimedia complexes on lecture* makes it possible; as the professor may organize a lecture in the form of dialogue with students at computer demonstration. Students participate actively in discussion and solution of problems raised on lecture; the student applies his knowledge in the form of notions solving the problems and increases the level of its mastering. In this case each new notion is thoroughly comprehended; skills and abilities are trained, logic connection is established. Computer demonstration serves as a mean of solving the problem.

Students often ask the question about the appropriateness of obtaining this or that knowledge of subject field and if the professor is not possible to persuade them not only in its necessity for final test then further inte-

rest to the subject decreases as well as motivation, it is really strange to obtain new knowledge for its further control. Such kind of questions occurs from time to time even if they are not said aloud. Therefore, the task of the professor not only to give new knowledge but also student motivation to master it. One of the ways of motivation may be implemented when showing the connection of the knowledge obtained here and now with disciplines which are studied later i. e. on the basis of intersubject connection; for this purpose visual objects which may be obtained by computer maintenance are the most suitable.

Let us consider the technique of introduction of computer demonstrations and experiment for problem learning stimulating solution of problem situation by a concrete example.

As a rule, application of the theorem of Ostrogradskii-Gauss for calculation of electric fields is considered for simple, important cases practically implemented. Let us consider one of them, and namely, the field of evenly charged fiber. For this case the evenly charged infinite fiber with constant linear density of charge τ is examined in scientific literature as a rule. Only at short distances from fiber strength \vec{E} does not depend on the angle on which there is a point relative to the fiber end and presents a number of radially divergent lines. The problem is defined: *in what way the pattern of the lines of electrostatic field strength if the straight line has finite sizes? Is it possible to accept section total charge as point charge and a field of charged section for point charge field? The cognitive process is more efficient if the student may create quickly images, idea of phenomenon* in this case the assigned task is solved faster [5].

Computer maintenance helps in graphic presentation of areas where the field of finite fiber may be presented as a field of point charge; it increases the efficiency of educational process as it gives mathematical solution visually.

Professor may act in two ways after problem statement. After some remarks from places about possibility or impossibility of such conception and explanation he may carry out computer demonstration which shows visually the existence of such fields and then to explain mathematically the existence of such fields. The second variant is to show analytically analyzing strength formulas the existence of such fields after problem statement and answers and then to give graphic solution of this problem with the help of the program.

Fragment of lecture with analytic analysis and graphic solution is given below.

Thin rod may be divided into smaller (ideally, infinitely small) sections with the length dl . On this section (Fig. 1) there is a charge $dq = \tau \cdot dl$, which may be considered as a point one owing to its smallness dl .

Module of strength of electrostatic field from point charge should be known

$$dE = \frac{1}{4\pi\epsilon_0} \frac{\tau dl}{r^2},$$

where $r = \frac{a}{\cos \alpha}$ is the distance from the marked element to the point where the strength is searched is expressed through the perpendicular descended from calculated point a , and angle α , on which this point is seen from marked element; $dl = \frac{rd\alpha}{\cos \alpha}$ is the elementary section of length.

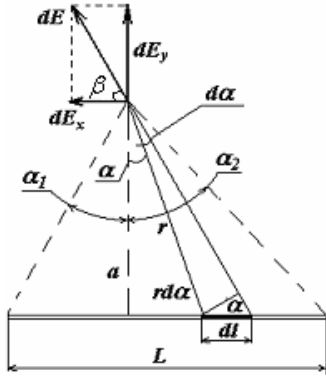


Fig. 1. For defining strength from the fiber of finite length

After substitution we obtain

$$dE = \frac{1}{4\pi\epsilon_0} \frac{\tau d\alpha}{a}$$

Let us decompose vector dE into two constituents: dE_1 – perpendicular and dE_2 – parallel to rod length. It is seen from the draft:

$$dE_y = \frac{1}{4\pi\epsilon_0} \frac{\tau d\alpha}{a} \cos \alpha;$$

$$dE_x = \frac{1}{4\pi\epsilon_0} \frac{\tau d\alpha}{a} \sin \alpha.$$

Let us integrate two last expressions by angle α from α_1 to α_2 for searching strength from all elementary sections

$$E_y = \frac{1}{4\pi\epsilon_0} \frac{\tau}{a} \int_{-\alpha_1}^{\alpha_2} \cos \alpha d\alpha = \frac{1}{4\pi\epsilon_0} \frac{\tau}{a} [\sin \alpha_2 + \sin \alpha_1];$$

$$E_x = \frac{1}{4\pi\epsilon_0} \frac{\tau}{a} \int_{-\alpha_1}^{\alpha_2} \sin \alpha d\alpha = \frac{1}{4\pi\epsilon_0} \frac{\tau}{a} [\cos \alpha_1 - \cos \alpha_2].$$

Resultant strength is determined by Pythagorean theorem

$$E = \sqrt{E_x^2 + E_y^2} = \frac{1}{4\pi\epsilon_0} \frac{\tau}{a} \sqrt{[\sin \alpha_2 + \sin \alpha_1]^2 + [\cos \alpha_1 - \cos \alpha_2]^2}.$$

After squaring, using trigonometric formulas we obtain

$$E = \frac{1}{4\pi\epsilon_0} \frac{\tau}{a} \sqrt{2[1 - \cos(\alpha_1 + \alpha_2)]}.$$

To simplify the analysis one can examine the particular case when $\alpha_1 = \alpha_2 = \alpha$, (for points on perpendicular reduced to fiber center) we obtain $2[1 - \cos(2\alpha)] = 4\sin^2 \alpha$ then the last formula is written down as

$$E = \frac{1}{2\pi\epsilon_0} \frac{\tau}{a} \sin \alpha.$$

It follows from Fig. 1 that $\sin \alpha = \frac{L/2}{\sqrt{(L/2)^2 + a^2}}$, then strength of electrostatic field on perpendicular bisector

$$E = \frac{1}{2\pi\epsilon_0} \frac{\tau}{a} \frac{L/2}{\sqrt{(L/2)^2 + a^2}}.$$

If the condition $L \ll a$ is fulfilled then $L \ll a$ and as $q = \tau \cdot L$ then $E \approx \frac{1}{4\pi\epsilon_0} \frac{q}{a^2}$, and this is the expression for determining strength from point charge. As electric field strength is characterized not only by the value but also by the direction then for complete comparison of electrostatic field of finite fiber and point charge field the strength direction should be taken into account, i. e. it is necessary to compare by two parameters: strength modulus and angle.

Let us show the way to do it. The angle of electric field vector of horizontal axis of finite fiber may be determined as

$$\beta = \frac{E_y}{E_x} = \text{arctg} \frac{\sin \alpha_2 + \sin \alpha_1}{\cos \alpha_1 - \cos \alpha_2} = \text{arctg} \left(\text{ctg} \frac{\alpha_2 - \alpha_1}{2} \right).$$

this very angle should be compared with the angle on which the design point is seen; where strength from center of section is compared (places of arrangement of equivalent point charge $q = \tau \cdot L$).

To simplify the analysis the particular case when $\alpha_1 = \alpha_2 = \alpha$, may be considered for any points on perpendicular bisector we obtain: $\beta = \text{arctg}(\text{ctg} \frac{0}{2}) = 90^\circ$.

Angle on which the points being on perpendicular relative to the point charge are seen equals to 90° as well. Therefore, comparing strength for points being on perpendicular bisector recovered to the center of the section only strength modules formed by point charge and finite conductor may be compared.

In general case it is necessary to compare both by angle and by strength modules. The detailed analysis is very labor-consuming therefore it is sensible to use software for visual presentation of solution of this problem. Computer implementation of this problem is given in Fig. 2. Areas of electrostatic field where field can not be examined as point charge field (with particular degree of accuracy) are shown in white color. Areas corresponding to the region of space where the field may be presented as point charge field are shown in grey color.

Computer implementation of this example shows visually that in the case of uniformly charged fiber with finite length L the expression for strength $E = \frac{\tau}{2\pi\epsilon_0 a}$ is

valid for field points being at distance a from the charged section rather small in comparison with L and not very close to its edges. Electric field stops being uniform near charged section edges even at a distance comparable with section size (Fig. 2, a).

If distance a is of order of charged fiber then field value and direction in the space are changed very difficult. At rather long distances in comparison with fiber size the charged fiber acts as point charge – the field decreases inversely as the square of the distance.

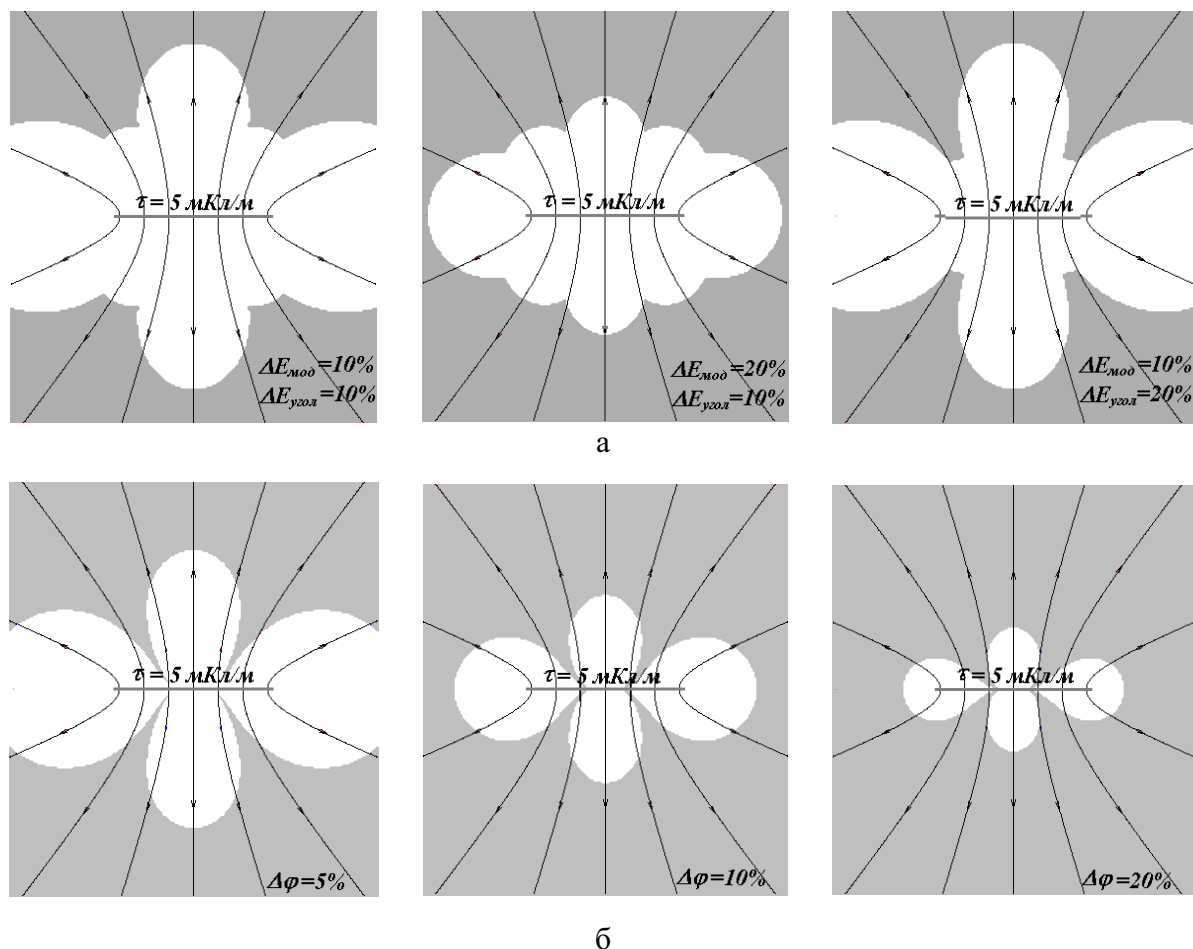


Fig. 2. Comparison of finite fiber field with point charge field: a) in field strength; b) in potential

Electrostatic fields may be compared not only by power characteristic but also by energy one that is electric potential. The technique of formula derivation for potential generated by a charged section is similar to formula derivation for strength therefore it may be written down without derivation in the following way

$$\varphi = \frac{\tau}{4\pi\epsilon_0} \left(\ln \left| \operatorname{tg} \left(\frac{\alpha_2}{2} + \frac{\pi}{4} \right) \right| - \ln \left| \operatorname{tg} \left(-\frac{\alpha_1}{2} + \frac{\pi}{4} \right) \right| \right).$$

For points on perpendicular bisector we obtain

$$\varphi = \frac{\tau}{2\pi\epsilon_0} \ln \left| \operatorname{tg} \left(\frac{\alpha}{2} + \frac{\pi}{4} \right) \right|.$$

Further comparison is carried out by computer (Fig. 2, b) and similar conclusions are drawn as in the case of strength comparison.

Studying this subject students of engineering and electrotechnical specialties are motivated in the following way. To explain them that they calculate electric capacities of various conductors, in particular, capacity of real flat condenser having finite dimensions in the subject «theory of electrotechnics». One of the ways of calculating capacities consists in analysis of field pattern. Flat condenser plates may be presented in the form of infinite number of finite charged sections then condenser field may be determined by superposition principle. Total field pattern in this case is shown in Fig. 3.

Then the results of computer experiment may be shown (Fig. 4), explaining that such field pattern is obtained on the basis of other technique and namely, by conformal mapping method; the essence of the method should not be explained it is enough to mention its names.

Then it is important to emphasize that it is important to know electric field parameters from practical point of view [6]. For example, strength value is very important at design of condensers meant for higher stress. If electric field strength is very high then dielectric breakdown may occur. Using condensers for obtaining uniform electric field it is very important to find out at what the distance from the condenser edge the field may be considered as practically uniform. It follows from Fig. 3 and 4 that at the distance from condenser edge having an order of distance between condenser plates the field may be considered uniform at fine precision. Thus, the motivation of obtaining new knowledge may be increased by computer experiment.

Lectures which do not require active student work make semblance of simplicity and extreme accessibility of material, dull their activity and result in placidity. It lulls student cognitive desire and impedes their development. The development of problem situation at lectures makes student think and development of certain difficulties in learning (however, not formal ones but such which make student show creation) raise them, form

their will and tendency to overcome this difficulty. Difficulties should be complicated by a lecturer at further material statement but they should be always surmountable. Difficulty overcoming in mastering knowledge influences favorably student psychic. He acquires self-confidence in his force and accustoms oneself to self-dependence and creativity.

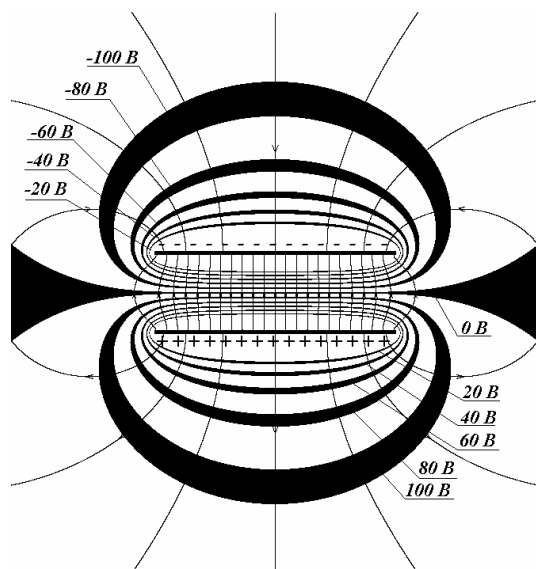


Fig. 3. Pattern of the flat condenser field (original data $\sigma=30 \text{ nC/m}^2$, $2h=1 \text{ cm}$ $2a=3 \text{ cm}$)

Having developed such conditions it is necessary to help student: give him the means of objective self-control of results; so that achieving any conclusions by himself he can be sure in truth of his activities. Here computer acts as an installation for carrying out physical ex-

periments. Such experiment may be both the final part of explanation of some subject (computer demonstration or experiment acts as a mean of problem solution) and peculiar lecture canvas; lecturing the professor uses alternately auditorium blackboard or software.

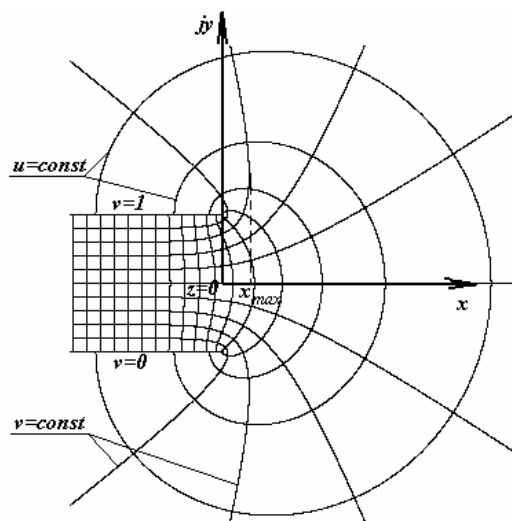


Fig. 4. Field at the edge of flat condenser constructed by conformal mapping method (at $\Delta u=4$ $\Delta v=4$)

In conclusion, let us note the aims which may be achieved by introduction of computer maintenance at lectures: formation of deep and sound knowledge, development of creative thinking when person contributes mental efforts into the process of knowledge mastering and they become the source of sensible activity and development. Besides, application of computer experiment is possible for development of motivation for learning.

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