Organization and realization of the experimental cycle of scientific cognition at Physics study

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Abstract

The article is dedicated to the methodology of educational activity of Ukrainian pupils during physics study. There are presented the authors' methodical developments of organization and realization of the experimental cycle of scientific cognition in the process of arrangement of experimental Physics problems (research of elastic properties of solids, research of strain gauge action, definition of the liquid surface tension, and determination of Quality factor (*Q* factor) of a simple pendulum. The laboratory equipment includes simple digital measuring devices and author's home-made equipment that makes possible realization of the offered problems in an educational physics experiment**.**

Keywords: Scientific method of cognition, theoretical and experimental methods of physics, educational physics experiment.

Resumen

El artículo está dedicado a la metodología de la actividad educativa de los alumnos de Ucrania durante el estudio de la física. Se presentan los desarrollos metodológicos de los autores que tratan acerca de la organización y realización del ciclo experimental del conocimiento científico en el proceso de arreglo de problemas experimentales de Física (investigación de las propiedades elásticas de los sólidos, la investigación de la acción del calibrador de tensión, la definición de la tensión superficial del líquido, y determinación del factor de calidad [factor *Q*] de un péndulo simple). El equipo de laboratorio incluye dispositivos de medición digitales y equipos sencillos hechos en casa del autor, que hacen posible la realización de los problemas que se ofrecen, en un experimento de física educativa.

Palabras clave: Método científico de la cognición, métodos teóricos y experimentales de la física, experimento de física educativa.

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I. INTRODUCTION

Methodology of educational-cognitive activity is one of the basic sources of development and modernization of physics teaching methods. It is based on the modern scientific methods of cognition of the physics phenomena and processes. A scientific method is an instrument of cognitive and creative initiative development of pupils; it encourages their independent thinking and activity. At the same time, a scientific method of cognition is a top of achievements of human culture; it has a long historical way of development and has become the basis of culturological approach to physics study.

Improvement of teaching methods aimed at personal development, easy orientation in informatization society, formation of adaptable abilities to overcome difficulties is an important issue of teaching physics methods. Physics study is aimed to independent intellectual ability creating, knowledge obtaining and application, activities appropriate consideration and organization, the tasks solution seeking; it requires alternative forms and ways of activity implementation in the educational process where essential role is assigned to the research activities of learners. This activity is designed to promote their skills through the world cognition as vital quality of every person.

However, when planning such activities, we should take into account the differences between scientists' research activities and research activities of pupils. The model of research methodology for pupils is taken from the methods that are developed and adopted in science over the last few centuries. This model is characterized by several standard phases; they are present in any scientific study regardless of a field of activity. Thus, from a functional point of view, the main aim of educational research is fundamentally different from the aim of scientific research. The main aim of science is to produce absolutely new knowledge; the aim of education is to build pupils' functional skills of research as universal way of understanding of reality through increase of motivation of learning activity and activation of pupils' personal positions in the learning process; it is based on a gaining subjective new knowledge (i.e., self-obtained knowledge that is new and personally meaningful for a particular learner). Founding on our own experience of organization of pupils research activity during physics study, we present how this activity can be a tool for developing pupils' learning motivation and a powerful regulator of the education quality.

In part II, we show how physics was developed as a science in its modern sense relative to methods of nature cognition. In part III, we present a brief discussion of modern methods of teaching physics as for their coordination with the cycle of scientific understanding of nature. We offer our vision of the solution for the problem of organization of pupils' research activity coordination with the cycle of scientific understanding of nature. We present versions of the relevant experimental tasks: study of elastic properties of solids; study of a strain gauge; liquid surface tension; determination of the simple pendulum quality factor. A characteristic feature of these problems is the fact that the identification of the observed physical parameters is aimed to their direct measurements by digital instrumentation developed as a part of our experimental settings. In part IV, we present our conclusions that point to the need for approximation of the methods of scientific knowledge for methods of teaching physics. Therefore, we confirm priority of pupils' research activities at solving physics experimental problems, which puts pupils into position of the researcher, scientist, and discoverer. The article is concluded by the presentation of prospects of development of the problematic of future teachers of physics education.

II. REVIEW OF PROBLEMS AT PRESENT STAGE

The development of physics as a science in nowadays understanding has been founded in XVII century and firstly associated with the name of G. Galileo, who in contradistinction to predecessor considered that the cause of the phenomena can differ from imagined during an observation. Among many expressions of Galileo, it is possible to distinguish basic one concerning methodology of scientific cognition: "Perceptible experiment, working hypothesis, mathematical development, and experiment verification – these are four phases of the phenomena of nature research; it has begun with experiment and completed them, but cannot develop without an application of mathematics" [1].

Follower of G. Galileo, I. Newton not only successfully used the scientific method of cognition; it acquired further development in his works. Newton saw in methodology of physics as a science not only the stages of cognition but also a strategy of research of nature; he wrote in the work "Philosophiae Naturalis Principia Mathematica" by Sir Isaac Newton (1686) that "All difficulty of physics, as will be seen, is to recognize forces of nature in the phenomenon of motion and then explain other phenomena by these forces" [2].

The most complete and definite opinion of essence of modern scientific method of cognition, in our opinion, belongs to A. Einstein (1952): "(1) the known quantity “E” – there are directly data of perceptible experiment. (2) Quantities “A” - are axioms from which we output the results. Psychologically “A” is based on “E”. But there is no logical explanation that “E” leads to “A”. There is only intuitive (psychological) link which never stops to renovate. (3) Statements “S” are derived from axioms “A”, and can pretend on rigorous determination. (4) Statements “S” are compared with “E” (test experiment). Consequently, this procedure refers to the illogical (intuitive) areas, because the ratio of concepts of “S” concerns directly data of sensory experiment “E”" [3].

Thus, A. Einstein determined that the process of scientific cognition is a cycle that begins and ends with an experiment. The cycle of cognition consists of four phases: 1) collection of experimental data and formulation of the problem; 2) proposition of the hypothesis-axiom; 3) mathematical interpretation of the hypothesis, logical conclusion from its consequences; 4) experimental testing the hypothesis and its consequences.

In the didactics of physics, a cycle of scientific cognition must be adapted to the requirement of modern pedagogic; that is why a problem of approximation of theoretical and experimental methods of physics to the theoretical methods of studies and methodology of physics study of is very relevant.

III. AN ANALYSIS OF KEY PEDAGOGICAL METHODS AND MEANS OF MODERN PHYSICAL EDUCATION

In 70th of past century in methodology of physics study of soviet union' general school an academician V. Razumovskiy succeeded to find for the first time a principle of recurrence - an universal methodological instrument for organization of process of educational cognition. It was presented by logical chain of organization of educational-cognitive activity: "facts, a problem – a supposition, a model - consequence - experiment, practice" [4]. Principle of recurrence in an obvious and non-obvious form is the norm of cognition that is specified for two leading types of educational activity - experimentation and design that are approximated from the methods of scientific cognition of the physics phenomena and processes - experimental and theoretical, which are equal and complementary in physics.

The theoretical cycle of scientific cognition (Fig. 1a) begins with the study of facts, which have proved experimentally or in theory. The examination of facts leads to considerations and bringing up guesswork about physical nature of the investigated phenomenon. Facts are explained by the theoretical model of the phenomenon. The basis of the model consists of qualitative physical and quantitative mathematical models. A model is a hypothesis that is impossible to direct justify by experiment. That's why according to a model and logically reasoning, consequences should be determined. Those consequences are both quality and quantitative values and need experimental verification. If an experiment confirms that the consequences of model correspond to reality, a model is considered to be reasonable within its applicability.

Scientific cognition is provided not only in theoretical cycle, but also in the experimental one (Fig. 1b). An experiment consists of several stages. First of all, it is needed to create conditions of the experiment. The results of experiment are analyzed and interpreted. These give new information about the investigated object, and new facts complement the existent system of knowledge.

Therefore, the complete cycle of scientific cognition in physics consists of two equivalent components: theory and experiment. Moreover, the theories include facts, models, and consequences; experiment includes conditions, result, and interpretation, Fig. 1.

There are several key points of the scientific cognition cycle teaching methodology. Firstly, a transition from facts to the model should be carry out in joint activities of the teacher and the pupil without references to authorities, in every way encouraging their independently putting forward true hypothesis. Secondly, when transiting from the consequences of theory to the terms of experiment, pupils must be acquainted with modern possibilities of experimentation. Thirdly, the system of experiments that describes a physical theory must consist of the demonstration, laboratory forms of educational experiment, and implementation of additional experimental problems that provides effective organization of educational-cognitive activity, also including researching work.

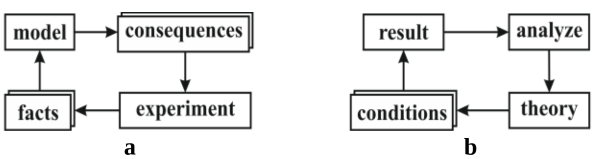

FIGURE 1. Experimental (a) and theoretical (b) cycles of scientific cognition.

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Optimally is when an educational experiment is closely related with the theoretical bases of the physical process or phenomenon that are investigating. It means that such experiment is not illustrative, but evidential, and its result gives full explanation. It accentuates the importance of a question of providing of sufficient teachers of physics training and provision of experimental devices that are necessary because of hard requirements of presence of educational experiment practically at each lesson [5].

In the process of scientific cognition, a transition from facts to the model and from consequences to the experiment carries intuitional character that is why these facts determine essence of thinking of pupils.

A. Experimental physics problems

Solving of physics problems leads to development of pupils' thinking. However, computational problems can investigate only the theoretical models of the phenomenon and do not penetrate deep in processes that form physics thought. In other words, it is possible to learn how to solve problems, but do not learn physics.

Another situation is experimental problems solving where the first thing is facts searching about formulation of data of the problem and then a theoretical model creating. The other case is when the result of theoretical solving confirms an experiment. Every of the problems can be realized by demonstration or frontal variant or be a part of the research work in accordance with the types of educational experiment. The question of development and adjustment of experimental problems is very actual one.

Installation and fulfillment of educational physics experiment requires special conditions for its realization; the equipment must be prepared, the experimental installations must be collected and finally an experiment must be properly conducted. When getting a result in the process of observation of the phenomenon, the attention must be paid to its basic features. If it is possible, quantitative description of the investigated phenomenon should be determined. In the process of analyzing, it must be held comparison between the received result and the results of other experiments. Also, it is necessary to explain received result and predict the new phenomena. Set of experiments for explanation of the theoretical models of the physics phenomena, problematic and interesting experiments, and also experimental problems must be presented at almost every lesson and should be realized, if it is possible, by one of the variant.

Nowadays, standard classification of physics educational experiment according to forms of its realization (demonstration, laboratory work) needs detailed presentation of scientific methods of cognition of nature: fundamental, testing, applied, phenomenological, functional, natural, estimated, virtual, real, speculative, imaginary [5].

This article presents content of scientific cognition cycle using the examples of educational theory and educational experiment that is characterized by implementation of forms and methods of measuring by modern digital devices and by prompting variants of experimental problems creation. In this case, necessity of such implementations is characterized by the number of requirements in relation to initial equipment accessories in cabinets of physics and laboratories, in particular, principles of "minimum creates maximum", "increasing of the coefficient of usage of equipment", "integration of studying devices", "quantitative measuring in a demonstrative experiment" and others [6].

We offer the experimental installation that is collected on the base of digital measuring devices: electronic balance of SEJ Series and digital calipers; home-made equipment and typical equipment of physics cabinet.

B. Making the home-made equipment

A plate (1) with sizes of 4x50 cm is the durable foundation to fix the following: the pulleys (2) near the left and right edges; stretching mechanism (3) at the right edge; U-shaped holder (4) for fixation of the end of immobile part of calipers at the distance of 15 cm from the right edge, Fig. 2.

A bar 3x4 cm and 7 mm of thickness (5) is cut out from metal or textolite. It is made a cut on the bar, as a result, a riffle appears; and the left part of calipers is fixed on it by a clamp of tin. A pulley (6) is fixed to the top part of the bar, with its help the calipers is based on the upper bound of the plate. A hole is making and cutting the thread of M 5 at the distance of 1 cm from the top edge of the bar. A screw (7) with a corresponding thread presses two rectangular pucks (8). The left edges of specimen (wire strands, sensors), which are investigated in the experiment, are clamping between the pucks. The right edge of movable part of calipers is clamped between the low edges of two metallic plates (9) with size of 1 x 2.5 cm. A hole with the thread of M 5 is made through the upper edges of the plate. A screw (10) with a corresponding thread presses two pucks to the bar; the right edges of specimen are clamped between the pucks.

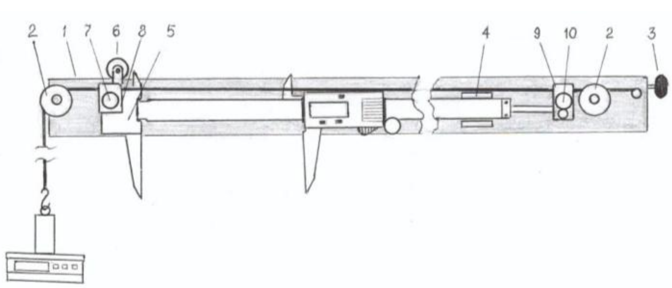

FIGURE 2. Installation collected on the base of digital measuring devices.

Metal rods 5-10 cm long are fixing to inverse side of the plate (1) at the distances of 5 cm from its edges; with their help, the plate with details is fixing horizontally on the racks of two tripods.

C. Examples of physical experimental Problems

Problem 1. Research of resilient properties of solids.

Equipment: 1) Installation collected on the base of digital measuring devices; 2) Micrometer; 3) Electronic scales; 4) Ruler; 5) Wires made from different materials, rubber band.

Contents and the problem processing.

Stiffness k of the deformed sample is related to its initial length l_0 and to cross-section area S by:

$$k = E\frac{S}{l_0}, \qquad (1)$$

where E is elastic modulus calculated by a formula

$$E = \frac{Fl_0}{S\cdot|\Delta l|}, \qquad (2)$$

where F is a force of elasticity determined by law of Hooke as

$$F = -k\Delta l, \qquad (3)$$

where Δl is a linear elongation of the sample.

Measuring the elastic modulus of the investigated sample (homogeneous thin cylindrical form wire) using offered by us device allows doing it with the adequate accuracy. The obtained results of measuring are similar to the table values, which are given in the special reference book.

Straightened section of the wire is fixed between pucks 8 and 10 as shown on Fig. 2. The left end is attached to the weight on the scales by means of the hook; right end of the wire is attached to the clamp mechanism 3. The general view of the installation is presented on Fig. 3.

FIGURE 3. The experimental installation for research of resilient properties of solids.

The experiment fulfillment is following: turn on measuring devices; indications of electronic scales set on zero; stretch a wire until the indications on the panel of scales will differ from zero; set indications on the panel of scales and electronic calipers at zero again.

Begin measuring with length of the investigated sample l_0 between pucks 8 and 10. Stretch out the sample with the help of mechanism 3 and measure indications of F (electronic scales) and Δl (electronic calipers) several times. The cross-section of the wire S is measured by a micrometer.

If we replace a metallic wire in the offered experimental installation by the rubber band of considerable thickness, it will be possible to investigate elastic properties of rubber. We can formulate corresponding experimental problem where the process of linear stretch of rubber band will be investigated depending on change of the rubber band cross-section during its deformation. Measuring of the rubber band diameter or thickness can be done by micrometer with accuracy up to hundredths of a millimeter.

Offered by us implementations of the problems of research of properties of solids during their deformation in mechanics acquire further development in classic electrodynamics. In particular, conductivity (resistance) of wires depends on their shape and geometrical sizes.

Problem 2. Research of action of strain gauge.

Equipment: 1) Installation collected on the base of digital measuring devices; 2) Micrometers; 3) Ruler; 4) Bridge for resistance measure; 5) the metallic strip with stuck strain gauge transducer.

Contents and the problem processing.

We used strain gauge transducer with resistance of 100 Ω stuck on a metallic (duralumin) strip. The length of the strip allows fixing its ends between pucks 8 and 10. Also the edges of steel wires are fixed to these pucks. Other edges of the steel wires are attached to the left block and to the tension mechanism.

Contacts of the strain gauge are connected to the ohmmeter or, for more exact measuring, to the resistance bridge.

The main objective of the problem is to research qualitatively the dependence of resistance of a sample on its geometrical sizes. In the problem, the size of the sample is a size of the strip with the stuck strain gauge transducer. Because of a size of the strain gauge transducer is less than the strip, the change of the transducer length and width depends on changes of the strip. Therefore, the change of the transducer length

$$\Delta l_t = \frac{l_t}{l_S} \cdot \Delta l_S \,. \qquad (4)$$

The results of measuring depend on selection of a material of high quality and sizes of the strip. If received values are qualitative, it is possible to determine the coefficient of sensitiveness of the strain gauge transducer that is determined by the formula:

$$K = \frac{\Delta R / R}{\Delta l / l}. \qquad (5)$$

At the same time, by means of our experimental installation, it is possible to make implementation of other experimental problems: measuring of coefficients of deformations of different types; determination of transfer coefficient of strain gauge transducer, determination of structure and action of electronic scales.

Problem 3. Determination of surface-tension of liquids.

Equipment: 1) Installation collected on the base of digital measuring devices; 2) Electronic scales; 3) lifting unit from the device for "Demonstration of surface-tension" (DST); 4) Ruler; 5) Calipers.

Contents and the problem processing.

This installation is analogical to the installation that we made for determination of surface-tension DST. In the new installation, the left end of a thread is thrown over the block and attached to the load on the electronic scales; the thread right end is attached to the ring or to wire framework those contacts with the surface of the liquid in a glass. The glass is placed on a stand, which is slowly lowered or lifted by means of the screw at the bottom of the holder rotation, Fig. 4.

The problem is to measure a ring or framework size and determine the length of connection of the ring with the liquid where the force of surface tension *F* acts. For relatively small thickness of the framework or ring, the length equals the double length of the ring or to perimeter of the frame.

When the installation is compiled, scales should be switched on and the stand with the glass should be lifted to the complete contact of the ring (framework) with the surface of the liquid. Then, the stand is slowly lowered and we can watch readings of the scales. When readings begin change, we set the previous display value of the scales and set zeros on the indicator board. Then we begin slowly lower the stand with the glass filled by a liquid, watching readings of the scales. Maximum value when the ring unstuck from the surface of the liquid are measured. Experiment is repeated several times and the average value of surface tension of the liquid is determined.

FIGURE 4. The experimental installation for determination of surface tension of liquids.

It is worth to notice that quality of the experimental data is sufficient for implementation of research problems for determination of surface tension of different liquids. In particular, researches of dependence of surface tension of solutions (for example, solutions of sugar) on its concentration with the graphic image of corresponding experimental dependence. Experimental curves allow the calculation of sugar concentration in the test solution.

***Problem 4. Determination of Quality factor (Q factor) of a simple pendulum*.**

Equipment: 1) Installation collected on the base of digital measuring devices; 2) Electronic scales; 3) Laboratory tripod with couplings; 4) Ruler; 5) Starting electromagnet; 6) DC power source; 7) button switches; 8)conductors.

Contents and the problem processing.

If an oscillating system (simple pendulum, elastic pendulum, oscillating circuit, etc.) performs free oscillations (moving only under the action of internal forces), its oscillations are harmonic. But almost any oscillating system actually performs damped oscillations when its deviation from the equilibrium is gradually reduced. Such oscillations are inharmonious (an amplitude loses meaning in a literal sense as well as a frequency). However, when weakly damped oscillations (eg, friction force is much less then the elastic force), the damped oscillations are considered close to sinusoidal, they have a variable amplitude and a conditional period.

Variable amplitude is the maximum deviation from the equilibrium position value, which depends on time by a downward exponential progression.

Conditional period is a time interval between two successive maximum deviations from the equilibrium position in the same way. Then:

$$x(t) = A_0 e^{-\beta t} \cos(\omega t + \alpha_0), \quad (6)$$

where A_0 is the initial amplitude ($t = 0$); β is a damping factor; ω is a conventional frequency of damped oscillations, wherein:

$$A = A_0 e^{-\beta t};\ \omega = \sqrt{\omega_0^2 - \beta^2};\ \omega_0 = \sqrt{\frac{k}{m}};\ \beta = \frac{c}{2m},$$

where c is a coefficient of friction. $F_F = -c\mathrm{v}$ is a viscous friction force, which is proportional to the oscillation point linear velocity.

What do we need to understand under the expression "weak damping"? A quantitative characteristic of the oscillations damping degree (Q factor) is introduced for the aim. The main reason for oscillations disturbance is a quasi elastic force $F_E = -kx$, and the main reason of damping is a friction force $F_F = -c\mathrm{v}$.

Quality factor of a system is a characteristic of the system and the environment, which is numerically equal to the ratio of maximum elastic force to the maximum friction force, *i.e.*:

$$Q = \frac{F_E}{F_F} = \frac{kx_{\max}}{c\mathrm{v}_{\max}}. \quad (7)$$

But $x_{\max} = A$; $\mathrm{v}_{\max} = \omega_0 A$. (Here we consider that β is small and, therefore, $\omega \approx \omega_0$). As a result:

$$Q = \frac{k}{c\omega_0} = \frac{m\omega_0^2}{c\omega_0} = \frac{m\omega_0}{c} = \frac{\sqrt{km}}{c}. \quad (8)$$

Thus, experimental measurement of an oscillating system Q factor requires indirect measurements; therefore, it is not simple and clear for educational experimentation in physics. We propose another approach and choose as a basis a different definition of a damped oscillatory system.

For a simple pendulum, is defined as the ratio of the total energy W to the value of the energy loss for the quarter period W_1 due to its dissipation (loss of energy due to friction). Then, Q factor for the damped oscillatory system can be written as

$$Q = \frac{W}{W_1}. \quad (9)$$

Performing the experiment consists in the following. First, we have to find the total mechanical energy of the pendulum, which it has at the beginning of oscillations, then, to find loss of part of this energy for a quarter of its period.

The idea of the experiment is to study the oscillatory motion of the simple pendulum. The active part of the experimental setup is a tripod with a rod; a string with a metal ball hung up to the rod. Below the first rod, a second rod fastens so that the thread in the upright position (balance of the pendulum) just touches the lower rod, Fig. 5.

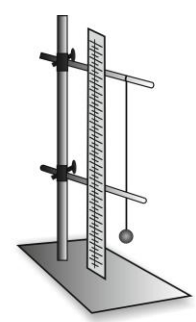

FIGURE 5. Schematic representation of the active part of the experimental setup for determination of the simple pendulum Q factor: tripod with fixed rods, the upper rod fixes the position of the pendulum; the lower rod adjusts its length.

In the initial position of the pendulum, the thread is horizontally stretched. Accordingly, the ball height for initial deflection of the pendulum is equal to its length l. The released ball moves to equilibrium; when it is reached, the pendulum will have a limit of the lower rod (thread catches on the lower rod), and oscillations continue but the pendulum length becomes less (it decreases by the distance between the rods on the tripod, for example, by $l_1/2$),

Fig. 6. Changing this distance, you can expect several consequences: the ball can describe a circle or circles around the lower rod; the ball can reach a top position with a vertically stretched thread and stop for a moment then fall vertically downward under the force of gravity until it compensates by the thread tension force. The latter result is interesting because complete loss of mechanical energy of the pendulum can be calculated without regard to its kinetic energy.

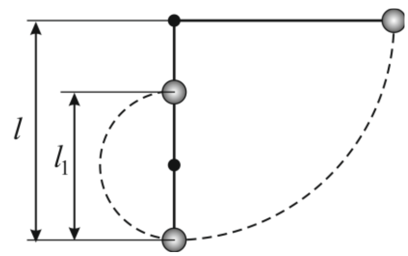

FIGURE 6. Schematic representation of the trajectory of the simple pendulum: l is the length of the pendulum at the beginning of the motion; $l_1/2$ is the length of the pendulum at the end of the motion.

Initial mechanical energy of the system is calculated by the formula

$$W = mgl, \tag{10}$$

where l is the entire length of the pendulum.

The value of energy when the ball reaches the upper vertical position second time:

$$W = mgl_1, \tag{11}$$

where l_1 is the height to which the pendulum rises reaching the vertical position second time.

Taking into consideration that the underlying oscillatory process lasts half the period of the pendulum (two quarter of the period), then the loss of energy by a quarter of the period can be written as

$$\Delta W = \frac{mg(l - l_1)}{2}. \tag{12}$$

Thus, according to the proposed conditions of the experiment, the quality factor of the oscillating system is defined as

$$Q = \frac{W}{\Delta W} = \frac{2mgl}{mg(l - l_1)} = \frac{2l}{l - l_1}. \tag{13}$$

Therefore, the performance of the experiment consists in finding the position of the lower rod when the ball does not continue a circular motion after the ball reaches the vertical position.

The experimental part of the work can be realized using an experimental setup based on the digital instrumentation (problem 1), involving an additional device for holding and starting the pendulum ball, Fig. 7. A launcher electromagnet is fixed on the tripod; an electromagnet from a lab kit for the preparation of an electromagnetic relay is used for this case. As a power supply, we can use any DC source of 4-6 V. As a convenient, a switch button with free closed contact can be used.

FIGURE 7. Experimental setup to determine Q factor of a simple pendulum.

End of the pendulum thread is attached to a load placed on a balance. The other end of the thread is thrown over a pulley on the installation; a metal (iron) ball is attached to the other end of the thread.

A horizontal rod is attached to the tripod. An electromagnet is attached to the rod so it supports the declined pendulum ball and the thread in horizontal position. A second rod is attached below to the tripod so that, when the pendulum is in equilibrium, the middle of the vertically oriented thread touches the second rod at the right side. Another thread is attached to the same end of the rod; it is taut and fixed by other end to the slider calipers (between washers by means of the screw 10).

Performing the experiment consist in finding the total mechanical energy of the pendulum, which it had at the beginning of oscillations, and loss of part of this energy for a quarter of its period.

The initial position of the pendulum is position of the horizontally stretched thread, where the ball is held by the electromagnet. Accordingly, height for initial deflection equal to the pendulum length l, which is carefully measured by the ruler. When the ball is released after the switch button pressing, the pendulum begins to oscillate and, after reaching the equilibrium position, the pendulum oscillation continues with smaller length $l/2$. Changing the distance l and measuring its change using calipers, we explore the consequences when the ball describes: circle, circles around the lower rod, the top position with vertically oriented and stretched thread, stopping for a moment to fall vertically downward under the influence of gravity. The last case is interesting in that the loss of total mechanical energy of the pendulum can be calculated without regard to its kinetic energy according to the formula (13).

So, experimental part is to measure with appropriate precision values of shift of the rod against which the thread catches relative the position of the half-length of pendulum that is provided using digital calipers.

Otherwise the experimental problem is performed by measuring the force exerted to the ball when passing the equilibrium position at half period time, 3/2 period time, etc. This force is measured by the electronic scales deflection, the initial set of the scales has to be zero. The experiment is repeated several times fixing the maximum value of the force and determining the average value for each experiment.

The proposed variant of the experimental display of damped mechanical oscillations is also available and appropriate to complement the formation of oscillation-wave concenters in physics course for specialized schools.

IV. CONCLUSIONS

The above-mentioned samples of organization of development and implementation of experimental problems are the examples of providing of quality of scientific cognition of pupils in the area of determination of physical essence of the investigated properties of solids and liquids. At the same time, there are examples of realization of conclusions about the necessity of introduction into the educational physics experiment of research and applied contents, phenomenological, functional and constant experiments that justify corresponding theoretical information and make possible the realization of the problematic and interesting experiments in the contents of corresponding experimental problems at physics study.

The analysis of methodological aspect of physics in its historical development shows its cultural value, educational and developing potential. Physics study must form a valuable relationship not only to the scientific discovery but also to the methods of scientific cognition, to the research methods, to methodology of science. Systematization of the scientific discoveries promotes the reflection of the world scientific picture and forming the scientific world view. The scientific methods of cognition and methods of research of the phenomena of nature in the education contents must orientate pupils to independent cognitive activity and to enable developing their cognitive and creative flairs. Authors executed an attempt of realization of these ideas creating manuals for the future teachers of physics [7, 8, 9, 10].

High level of systematization of physics knowledge obtained and tested by the experimental methods of physics, logical completeness of basic theories, deep penetration of mathematics in it allow considering physics as a standard of knowledge of the nature, inaccessible to majority of sciences. At the same time, the extreme latitude of practical physics applications allowed physics to become the basic instrument of technical progress; inextricable links of physics with technique that mutually enriches these two industries that have tendency to merger is one of the main features of modern physics. The teachers of physics, scientists-teachers, psychologists, teaching methods specialist search ways of creation of the integral system of physics education that satisfies the modern society scientific development.

In spite of rather high estimation of the achievements of scientists, it is worth to notice that the process of providing of pedagogical universities students by modern knowledge and newest scientific methods of physics is associated with the presence of certain contradictions between: methodology of physics based on the experimental and theoretical methods of research of its objects and the experimental and theoretical methods of physics study in the didactics of physics; the modern level of education of teachers and lecturers of physics and state of realization of fundamental physics education in a pedagogical university; the modern demand of society for the professional level of the future teachers of physics and actual level of their professionally-methodical education.

These contradictions stimulate to settle a number of problems related to physics study at a pedagogical university: by freshmen adaptation to the system of physics teaching at higher school; by the scientific level of complex presentation of experimental and theoretical methods of physics in the corresponding system of teaching; by realization of the sequence between subjects on different educationally-qualifying levels (bachelor, specialist, master's degree, that exist at higher school of Ukraine); by realization of recurrence in studying the experimental and theoretical methods of physics; by interdisciplinary integration of subjects of fundamental, professional-practical and methodical education of students; modernizations of control and evaluations of educational achievements of students studying physics in the conditions of the credit-module system of organization of educational process; organizations of independent work of students et cetera.

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