Ministry of Education and Science of Ukraine

Kharkiv National Automobile and Highway University

Automobile Faculty

Technical Operation and Service of Cars Department named after Govorushchenko M.Ya.

Nazarov A.

Synopsis of lectures from the discipline «Theory and methods of scientific creativity» full-time students in the specialty 274 «Motor vehicle transport» by educational and qualification level – bachelor

Kharkiv – 2025

UDC 629.01

Nazarov A. Synopsis of lectures from the discipline «Theory and methods of scientific creativity» full-time students in the specialty 274 «Motor vehicle transport» by educational and qualification level – bachelor. Kharkiv: KhNAHU, 2025. 178 p.

The practical application of methods of scientific creativity of applicants is considered: a systematic approach to solving scientific and creative problems; searching for and selecting the best design solutions; evaluation of the results of scientific and technical creativity, modeling in scientific and technical creativity, organization, types and processes of scientific research and recommendations for presenting the results of scientific research.

Intended for bachelors of all forms of study in specialty 274 «Motor vehicle transport».

© Nazarov A., 2025
© Kharkiv National Automobile and Highway University, 2025

CONTENT

INTRODUCTION TO THE COURSE

One of the most important features of modern scientific and technical progress in road transport is the development of scientific bases for the formation of engineering solutions during the design, production and operation of the rolling stock of motor vehicle enterprises.

The tasks between operators, designers and researchers are increasingly converging. Specialists working in each of the branches of industry or national economy are inevitably faced with the need to conduct both theoretical and experimental scientific research.

The ability to conduct scientific research becomes a necessity for an engineer, because it is often only with their help that it is possible to take into account the specifics of specific conditions of production and identify reserves for increasing its efficiency. A specialist working in a certain industry, for example, in motor vehicles, is faced with the need to solve problems related to increasing the reliability of cars, reducing operating costs, improving power and economic indicators, reducing the toxicity of emissions and their volume, improving operational indicators, for example, starting qualities or operation of systems, with the development of control systems and many other issues.

A specialist in maintenance and repair of rolling stock of motor transport enterprises in his practical activity has to make many technical decisions that require scientific justification. This includes, for example, the choice of the structure of the technological process of the restoration of car units, optimization of processing modes and parameters of technological equipment, equipment of stations and zones, and other At the same time, the optimization criteria can be the characteristics of both the technological process itself (productivity, stability, and other) and the parts being restored (cost, accuracy, performance indicators, and other).

The acceleration of scientific and technical progress, the introduction of science into production, the need for a creative solution to production problems - all this directly affects the development of a higher school, which should train specialists at the level of modern requirements. If young specialists gain practical experience directly in production, then they should acquire research skills at universities. Therefore, scientific training of students is one of the most important forms of education.

A modern specialist should not only have deep professional theoretical and practical knowledge, but also have a minimum of knowledge in the field of scientific research. All this will allow you to independently pose and creatively solve various complex production issues. Therefore, the introduction of science into production determines the need to increase the level of engineering and technical workers.

The research work of students and masters is implemented in the following forms of the educational process: study of the course "Technology of scientific research", preparation of an essay on a given topic, separate research during the performance of laboratory work, preparation of a report and presentation at a scientific seminar, development of separate research questions in periods of practice and in course projects, summarization in graduation papers of all the experience of the GDR during the period of study. Along with this, in extracurricular time, a student can participate in the department's scientific research work, in the preparation of articles for publication, applications for inventions, and other

As a result of studying the theoretical course and performing experimental research, the student should master the methods of planning and organizing scientific research. For this, it is necessary to master the methods of planning an experiment, processing and analyzing its results, methods of conducting special technological studies (characteristics of reliability, accuracy of processing and quality of the surfaces of parts and the product as a whole, and other), as well as to know the possibilities of methods of increasing the reliability and quality of work with maintenance and repair of cars.

He must also be able to select and analyze the necessary information on the topic of scientific research; formulate its tasks and develop theoretical prerequisites; plan and conduct an experiment, process measurement results and evaluate errors and observations; compare the results of the experiment with theoretical prerequisites and formulate research conclusions. It is important for a student to acquire the skills of drawing up a report, preparing a report or an article based on the results of scientific research.

At the same time, in the very process of scientific research, even in different fields of technology, there is a lot in common, and having these general methods of conducting research can make the latter more effective, reduce the labor intensity of work, and avoid many mistakes.

The study and analysis of these general rules and methods of conducting scientific research is the task of this course.

LECTURE OUTLINE 1

PLAN

The object of the TMNT discipline is the processes of learning about the surrounding reality, the creative processes of developing theoretical and methodical knowledge, which create a problem in scientific research, improvement and creation of new scientific objects and technical systems.

The subject of the discipline is theory and methods of scientific knowledge of the surrounding reality, objective laws of development of technical objects, methodology of scientific research of processes and phenomena, creative thinking processes.

The goal of the educational discipline is to provide students with theoretical and practical knowledge for professional activities related to the need to solve scientific and technical problems for the improvement and creation of new technical objects and technological processes by forming students' knowledge of the theory and methods of scientific research, a complex of knowledge creative thinking, skills and ideas, which ensure that the student acquires a high professional qualification of a specialist.

The content of the TMSC discipline is laid out in three sections, which include 16 subsections (topics).

Having studied the discipline, the student should know:

1. Theoretical issues of scientific creativity (topics 1-5): essence and nature of technical creativity; structure of scientific research; signs of a creative personality; the nature and sources of contradictions in the "man - technical object - environment" system; stages of development of technical objects and management of technical creativity; evolutionary and revolutionary ways of development of technical objects.

2. Methods of scientific research (topics 6 - 12): information support of scientific research; scientific knowledge of the surrounding reality; theory and methods of scientific creativity of theoretical studies; empirical research; heuristic studies; expert systems for finding new ideas and making creative decisions; methodology of experimental research.

3. Practical application of scientific research methods (topics 13 – 16): methods of system analysis in solving scientific and creative tasks, morphological functional, informational description and analysis of objects of research and diagnosis; methodology for searching and selecting the best design and construction solutions; evaluation of the results of scientific and technical creativity: invention, utility model, marks for goods and services and their legal protection; modeling in scientific and technical creativity: methods of physical, mathematical, graphic and simulation modeling of the researched processes; organization, types and processes of scientific activity.

As a result of studying the discipline, students should be able to: formulate a scientific problem, goal, subject, object, stages of scientific research and research methods; find and analyze information about scientific problems; review scientific facts in a new aspect of the object of research at a qualitatively new level; understand scientific language and use it; find in a practical problem a creative scientific problem, methods of its solution, logically and reasonably reveal the main features of research; to use the methods and means of general scientific engineering disciplines related to the problems of road transport in research, to perform mathematical processing and interpretation of the results of the experiment.

1.1. The subject and essence of scientific and technical creativity

The object of creativity is the process of learning about the surrounding reality.

Creativity is the highest form of the human mind, as well as accumulated experience. The process of creativity has not yet been known to the level of an adequate model.

Science examines and studies the problems of the Mind, investigates the "mechanisms" of thinking. There are numerous hypotheses, moreover, separate operations included in the thinking process (for example, memorization, association, and other) have been described, but there is still no complete operational structure that reveals the thinking process at least on a purely descriptive level .

Regarding the human mind, the most common are phenomenological ideas, science has yet to reveal the process of thinking. The emergence of science as a form of human activity is closely related to the growth of human intelligence, his mathematical and spiritual interests.

The subject of science is interconnected forms of movement of matter or features of their reflection in the minds of people.

Scientific knowledge is designed to pave the way to practice, to provide theoretical foundations for solving practical problems.

The subject of technical creativity is material objects of nature in a certain aspect of cognition.

The goals of science are to describe, explain, and predict the processes and phenomena of the surrounding reality that make up the subject of its study on the basis of the laws it discovers.

In a broad sense, the goals of science are the knowledge of the laws of nature and society, the corresponding influence on nature and the obtaining of results useful to society. The main goal of technical creativity is the creation of objects in nature that did not exist at all, the improvement of nature itself.

Subjects that arose as a result of human activity and were previously unknown are also objective reality and objects of knowledge. This gives rise to many fundamentally important ideas about technical creativity, as well as about the sociological requirements for this type of human activity.

Labor includes the labor activity of a person aimed at obtaining a material product.

The spiritual sphere of activity includes art, the sphere of services and science. They provide the intellectual (spiritual) wealth of society.

Intellectual creative work aimed at obtaining and using new knowledge is considered a scientific activity.

The most important task of scientific activity is the formation of a system of knowledge that contributes to the most rational organization of industrial relations and the use of industrial forces in the interests of all members of society.

1.2. The essence and signs of technical creativity

The essence and nature of knowledge are of a social nature, they are directly related to the subject - the practical activity of a person, and are determined by it.

Creating something new is one of the forms of improvement and knowledge of the real objective world in which we live, which has a direct and indirect effect on our conscious activity.

From live contemplation to abstract thinking and from it to practice is such a dialectical way of learning the truth, objective reality.

In the function of cognition, there is a single executor - a person. It is the subject of creativity, as well as the subject of study in various fields of knowledge (psychology, physiology, biology, pedagogy, physics, technical means, and other).

A person is a special system that represents the unity of physical and spiritual, natural and social, hereditary and acquired. We (in this case) are interested in the most important, absent in all other nature, the ability of man to be creative in general, one of the types of which is technical creativity.

Creativity is a type of human activity that creates something qualitatively new that did not exist in nature before.

It has two aspects: psychological and philosophical. The subject of studying psychology is the "mechanism" of creativity, the process from its inception to completion. Philosophy, on the other hand, examines the essence and content of creativity.

Science considers creativity as a human activity that will transform the natural and social world in accordance with social and personal needs based on the objective laws of reality.

This phrase summarizes the entire general program of creativity: identifying its goal (social need), determining the means of achieving it (objective laws), organizing the interaction of these means, obtaining and evaluating results (conformity to the goal), implementation (use, implementation, exploitation) .

Creativity as a creative activity is characterized by originality and socio-historical uniqueness.

The main executor of the act of creativity is human thinking, which not only reflects the objective world, but also creates it.

Despite the manifestation of personal characteristics of a person as a creator in creativity, it is possible to single out the general thing that is characteristic of all types of creativity: the individuality of a person as a performer of an act of creativity; the complete identity of the psychological aspects of creativity in all its forms, since the "mechanisms" of creativity do not have (according to modern psychology) any specifically "technical" states; the independence of specific types of creativity from the principled philosophical provisions about accessibility to knowledge of the world.

Technical creativity takes place in relation to technique and technology - a component of the productive forces of society, the material basis of the existing social formation.

The level of technology determines the growth and development of productive forces, and in this connection it can be considered a tool for improving productive forces.

At the same time, there is also a reverse process of the influence of productive forces on the subject of creativity - a person. The social need for the development of technical creativity, as a complex element of scientific and technical progress, requires constant improvement.

One of the most important basic forms is teaching the basics of technical creativity. The dialectical method of learning technical creativity as a field of knowledge, in which the main laws of dialectics (unity and struggle of opposites, negation of negation, transition of quantity into quality) are clearly revealed, should be supplemented by some specific characteristics that belong to the nature of technical creativity as an art form.

As a form of art, technical creativity in form and content is not only a product, but also a part of the mental process, a higher form of mind.

Therefore, this feature should become a hierarchically higher link in the knowledge of the process of technical creativity based on the knowledge and discoveries of psychology, physiology and biology.

In the materialistic understanding of the essence of knowledge, conscious and subconscious, rational and irrational are represented "on equal terms".

Their unity - in interaction, their opposite - in everything else - this is one of the essences of the mind.

A meaningful analysis of the process of technical creativity as an integrative field of knowledge, which took a lot from psychology, systems engineering, bionics and cybernetics, allows us to assume the predominant role of human psychology in its creative activity.

Such an assumption does not deny the significant and positive role of specific methods of solving technical problems, but it is difficult to imagine the possibility of creating universal methods of solving them.

This conclusion follows from the following provisions: lack of adequate thinking models; lack of specific life cycle models of technical objects; an infinite variety of properties and characteristics of technical objects; the inadmissibility of introducing (even with the best intentions) any restrictions or advantages (except for ethical ones) in the selection of goals and means of their achievement for solving specific technical problems.

1.3 The structure of technical creativity as a process of creating competitive equipment and technology

In technical creativity, the interaction of man and the environment is a system of subjective (man) and objective (technique, environment) elements.

At the same time, technical creativity is a consistent change of states in the "man - technology" system.

In a socially significant aspect, technical creativity is a process of direct creativity, a system of learning the basics of creative activity, which, being mutually improved, has an increasing impact on technical progress.

The objects of scientific and technical creative and inventive activity of a person can be any technical devices in any fields of engineering, transport, medicine, agriculture and other countless areas to which the human mind can be applied.

Taking into account the various spheres of human intellectual activity, all objects can be divided into five groups of objects: official research and production activity; extracurricular activities; educational activity; born hobbies of a person; born of a happy accident.

In the technical fields of human activity, the processes of technical creativity appear in their socially significant aspect as the real creation of competitive (which is ahead of the achieved world level) equipment and technology and as a formative form of public education - a system of teaching the basics of technical creativity.

Let us consider the general cycle of creation and operation of new technology, which may have the following stages: the problem as the identification of the discrepancy between the social need and the technical possibility, the technical and economic justification of the solution to the problem, the idea of eliminating the discrepancy, a specific technical solution, design, production of a prototype, its testing and proofing, serial production and industrial operation, modernization, moral obsolescence, withdrawal from production and termination of use.

In fact, we have before us the entire life cycle of a technical object - from its "birth" to the end of its existence. At the same time, it is worth remembering about some artificial selection of this object, because the imprint of the set of technical means that make up the technical and technological base of the enterprise, industry, and national economy is imposed on it.

However, in our opinion, it is better to start studying the process of technical creativity with such a complete presentation of the life cycle of a technical object - new and competitive technology.

In this cycle, what distinguishes the created object of new technology from known domestic and foreign achievements, that is, adds to it a new set of consumer and other properties, is expressed by the materialization of an idea in a technical solution as a result of purposeful thinking work.

Technical creativity is a continuous process of creation that is not limited by the life cycle of a single, even complex, systemic, that is, quite complex (functionally and structurally) object.

After all, the entire retrospective experience of mankind in the creation of objects of engineering and technology, with all its achievements and failures, takes part in technical creativity (and at the same time actively!).

At the same time, the creation of some technical objects, as a rule, raises the question of the creation of other, next, better ones. And if we take into account the frequent cases of renewed interest in those "archaic" technical objects that seemed to have completely exhausted themselves (in this connection, we recall the fate of the first cars and airplanes), then the picture of technical creativity appears quite complex and even contradictory.

This is the dialectic of the development of productive forces within which technical creativity develops.

It should be noted that almost all components of the process of technical creativity are marked as creative moments, and the solution of each of the technical tasks set must meet all sociological requirements - objectivity, environmental friendliness, economy, and other

1.4 Organization of scientific activity in Ukraine

The organization of science in Ukraine is handled by the State Committee for Science and Technology in Ukraine, which together with scientific organizations determines the direction of the development of scientific research and its use in the national economy.

The state committee submits science development plans to the government or the Verkhovna Rada of Ukraine for approval and provision of funding from the state budget or other sources. This organization of scientific research management makes it possible to concentrate and focus science on the most important tasks.

The management of scientific activity is built according to the territorial and branch principle.

Today, research and development work is carried out by: research and project organizations and centers of the National Academy of Sciences of Ukraine (NASU); scientific-production, scientific-research, project organizations, systems of industry academies; research, project organizations and centers of ministries and departments; research organizations and departments of higher educational institutions; research and production, design organizations and centers of industrial enterprises and associations; the hierarchical top of this collection of organizations, centers, and enterprises is completed by the State Committee for Science and Technology, which ensures a unified state policy in the field of science and its use in practice.

The general classification of modern sciences establishes the relationship between three main divisions of scientific knowledge: natural science, social (social) sciences, and philosophy, each of which creates a whole system of sciences.

There is no generally accepted classification yet. They are divided into fundamental and applied, search, thematic and others.

Fundamental (theoretical) scientific research means: basic, main.

Both scientific theoretical and experimental activities are aimed at learning the laws governing the behavior and interaction of the basic structures of nature, society, and man.

The development of modern technology largely depends on progress in the field of fundamental sciences - mathematics, theoretical physics.

The highest state scientific center is the National Academy of

Sciences of Ukraine (NANU). It combines all areas of science and maintains international relations with scientific centers of other countries.

Together with the State Committee for Science and Technology of Ukraine, NASU leads and coordinates fundamental and applied research in various fields of science.

The branches of the National Academy of Sciences combine scientific research institutes (RIIs) leading the development of science in a specific field of knowledge.

Leading scientific forces are concentrated in them.

The management structure at the Research Institute is shown in fig. 1.1, (see Presentation to the lecture 1).

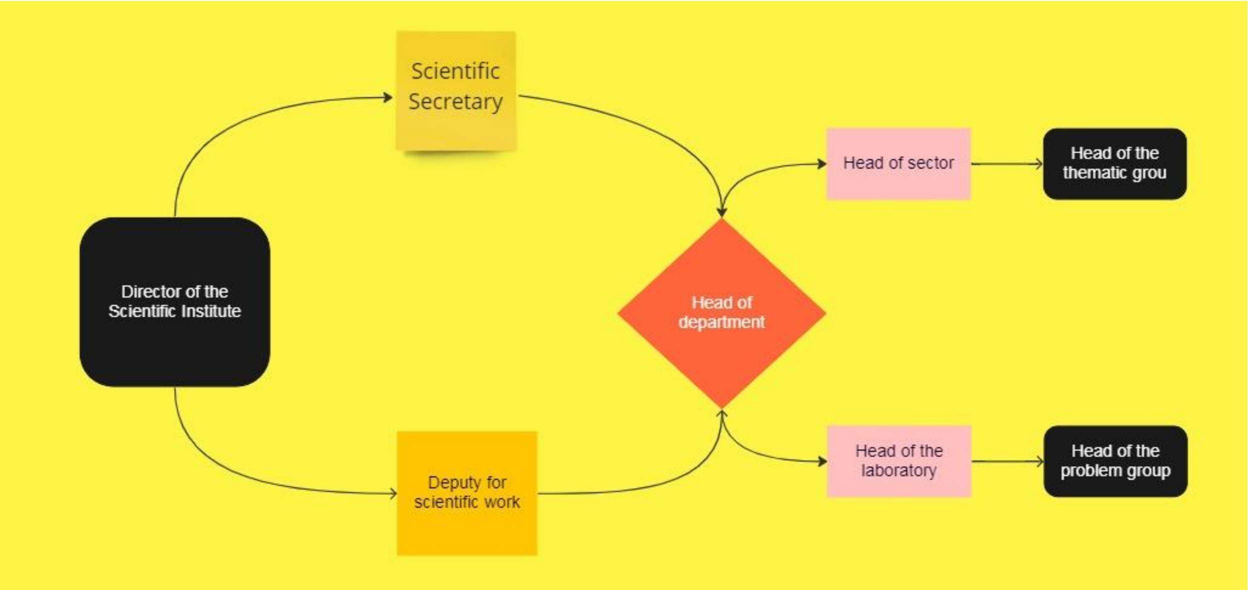

Figure 1.1 – Scheme of the management structure of the Research Institute

Applied scientific research is scientific and scientific-technical activity aimed at using the results of fundamental research for various practical tasks, on the basis of which new equipment, new machines, methods of production organization, technological processes, and other are developed. in order to obtain an economic effect in specific sectors of the economy.

Applied research can be planned, but fundamental research is difficult to plan.

Research activities of an applied nature are carried out at the Research Institute in departments, laboratories, and sectors.

Employees of the Research Institute are assigned the titles of junior researcher, research associate, senior researcher, leading researcher, chief researcher, head of the scientific department, head of the laboratory, deputy director of the Research Institute for Scientific Work.

Higher educational institutions have special divisions that carry out research work at the expense of state budget and self-financing funds.

The research is carried out by scientific and pedagogical workers with the involvement of students, young scientists, candidate and doctoral theses candidates on scientific subjects of higher educational institutions.

With regard to dissertations that have a special classification character, a more acceptable classification is scientific orientation.

According to the content and direction of the dissertation, it can be conditionally divided into four groups: theoretical, applied, informative and complex.

In dissertations of a theoretical nature, the researcher applies theoretical development and logical generalization of experimental data to identify patterns of phenomena and processes. Such works usually contain materials indicating ways of practical application of theoretical provisions.

The own logic of the development of each science (especially mathematical, philosophical and social) allows us to highlight such scientific results that do not yet have practical application, but in the scope of the dissertation expand the range of knowledge on the topic.

Dissertations of an applied nature focus on the material side of the single socio-historical process of knowledge and transformation of nature and society. The main purpose of such works: to show and substantiate the quantitative and qualitative aspects of the implementation of the specified theories; new real possibilities of their application in practice; technical, social, economic, aesthetic or other significance of specific theoretical provisions.

Dissertations of an informative nature (still relatively rare) reveal certain aspects of the theory of scientific information as an independent general scientific discipline.

In dissertations of a complex nature, theoretical and practical directions are not distinguished, but form a certain unity.

According to research methods and techniques, dissertations can be conditionally divided into groups: experimental, descriptive, computational-analytical, historical, polemical, mixed.

So, there are dissertations, theoretical, experimental, theoretical, descriptive, and other

Obtaining scientific results in the form of a scientific report has its own principles, methods, technique and technology.

The performer of scientific work must have a fairly clear general idea of the methodology of scientific creativity.

The abilities of the performer (scientist) are determined, first of all, by the results of his work, erudition and qualifications.

Erudition means broad and deep knowledge not only of the field of science in which he works, but also of related ones.

The most reliable and solid knowledge is obtained from primary sources. The performer of scientific work subjects them to critical analysis, creative processing, and systematically uses them in his activities.

The qualification of the performer is determined by a combination of high knowledge of the subject, erudition and creative skills in conducting theoretical and experimental works.

Modern scientific and theoretical thinking tries to get to the essence of the phenomena and processes being studied. This becomes possible under the conditions of a holistic approach to the object of study, consideration of its origin and development, that is, the use of a historical aspect.

The performer of scientific work, who has a wide erudition and creative skills, is able to critically interpret scientific information, evaluate its advantages and disadvantages, think "out of the box", find his own solutions, put forward new scientific ideas, know how to work with scientific equipment, computer equipment, carry out independent experiment, accumulate and analyze the necessary facts, generalize them, systematize them, explain them theoretically, make them in the form of a scientific report, articles, monographs, patents, reports, inventions.

Individual knowledge is formed and organized with the help of individual cognitive processes.

A person has his own individual cognitive (cognitive) style, which is manifested in individual differences in the perception and processing of information, as well as in the internal control of the adequacy of cognitive processes, their purposefulness, compliance with the requirements of the environment.

There are several cognitive styles [3].

1. Conceptual differentiation or non-differentiation - a person's tendency to distinguish objects using a large number of signs and make more accurate judgments about them, in contrast to the tendency to see

the general and distinguish objects by a small number of signs.

2. Smoothing or emphasizing differences - a person's tendency to simplify and lose details, as opposed to a tendency to emphasize and preserve them.

3. Flexibility or rigidity - a person's ability to switch to other types and methods of activity adequately to the requirements of reality, in contrast to the inability to do so.

4. Tolerance or resistance to new experiences that contradict one's knowledge - the ability to process unstructured, uncertain, ambiguous information as opposed to the inability to do so.

5. Narrowness or width of the scan. The ability to distribute and focus attention, accurately and in detail to reflect the situation, its significant features, to cover various aspects of the problem.

The process of cognition includes the accumulation of facts.

No science can exist without systematization and generalization, logical understanding of facts.

Although facts are as necessary to a scientist as air, they are not yet science taken separately. Facts become an integral part of scientific knowledge when they appear in a systematized, generalized form.

Scientific research is a purposeful study of phenomena and processes using scientific methods, analysis of the influence of various factors on them, as well as study of interactions between phenomena with the aim of obtaining convincingly proven and useful solutions for science and practice.

Scientific research is characterized by objectivity, repeatability, provenance and accuracy.

The purpose of scientific research is the general, objective and well-founded study of phenomena, processes, their characteristics, their relationship on the basis of the principles and methods of cognition developed in science, as well as obtaining the results of their introduction into production, which are useful for human activity, in order to increase its efficiency.

Work materials were used when drawing up the scheme [1-3].

Any scientific research, from the creative idea to the final design of the work, is carried out according to its own individual, unique order.

But it is possible to define some general approaches and requirements in that creative process, which is commonly called "study in scientific content".

It follows from the scheme that it is possible to study something only when something is already recognized as the starting point, undoubtedly ready in the mind. Such are recognized, for example, number, time, space, matter, form, motion, mass.

Modern scientific and theoretical thinking seeks to penetrate and learn the essence of objects and phenomena of the objective world. This is possible if dialectical materialism is accepted as a general methodology of natural science.

It is important that research topics correspond to the tasks of the modern development of theory and practice, the demands of the national economy and culture of the country.

The formulation of an idea in scientific methodology requires a holistic approach to the object of knowledge, the use of synthesis (as a general feature of modern science), consideration of the object in its origin and development, that is, a historical approach to the object.

It is known that new scientific results and previously accumulated knowledge are in a dialectical interaction.

Better and progressive from the old passes into the new and gives it strength and effectiveness. Sometimes the forgotten old is reborn again on a new scientific basis and lives, as it were, a second life, but in a different, more perfect form.

But it can also be the following: a fundamentally new scientific solution that rejects the old and is offered in an unprecedentedly new, almost fantastic form.

The modern scientific approach to research requires the selection of such aspects that increase the efficiency or coefficient of the scientist's useful effect.

Therefore, studying in a scientific context means also mastering the ability to quickly and correctly make decisions.

Setting the problem is the task of the big plan. Accordingly, the scientist who works to some extent as a "free artist" has more opportunities to reveal his individuality: he puts forward ideas, poses problems.

At the same time, it is natural to follow the following recommendations:

not to accept as truth anything that is not reliable and axiomatic;

divide complex questions into as many parts as are necessary to solve the problem (decomposition);

start research with simple and easy-to-learn things, then move on to complex and difficult things;

to dwell on all the details, to pay attention to everything, to be sure that nothing is missed.

To study in the scientific sense means to conduct exploratory research, as if looking into the future.

Imagination, fantasy, dreams, which are based on real achievements of science and technology, as mentioned above, are real factors of scientific research, add a romantic character to any searching creative work of a scientist.

A real fantasy, a dream is a function of real scientific creativity.

A scientist who does not know how to dream is like a bird without wings, whose horizons are always narrow. Although, in principle, every scientific research is a kind of search for something new.

To study in a scientific context is to apply scientific prediction, forecasting, and scientifically thought-out calculation well and reasonably.

As already mentioned above, happy, accidental discoveries are possible in science. But only planned, well-equipped scientific research with modern means reliably reveals and deeply learns objective regularities in nature.

To study in a scientific sense is to search and find, to formulate answers when solving complex problems in the form of simple and, if possible, sophisticated solutions.

But, as often happens in practice, a novice researcher chooses difficult and complex solutions where there is no need for it.

In scientific research, everything is important. Focusing attention on the main or key issues of the topic, one cannot ignore the so-called indirect facts that, at first glance, seem insignificant. It often happens that such extraneous facts and phenomena hide the beginnings of important discoveries.

To study in a scientific context means to be scientifically objective. Facts cannot be brushed aside just because they are difficult to explain or find practical application.

But it was not enough to establish some new scientific fact, it is important to give it an explanation from the standpoint of modern science, to show its general cognitive, theoretical, and if possible, practical, social significance.

Practice should be the first and main point of view of the theory of knowledge.

In the history of science, there are many examples when important discoveries remained little-known for many years, because they did not receive a sufficient theoretical explanation at the time.

The essence of what is new in science is not always clearly visible to the researcher himself and even to his contemporaries.

New scientific facts, discoveries, sometimes quite large, due to the fact that their meaning is poorly disclosed, can remain in the reserve of science for a long time and not be used in practice.

The results of scientific research are better, the higher the scientific level of conclusions and generalizations, the higher their probability and effectiveness.

Control questions and tasks for independent solution

1. What is the object and subject of technical creativity?
2. Define the subject and essence of science.
3. What is the main purpose of technical creativity?
4. What is the role of human psychology in creative activity?
5. List the common features characteristic of all types of creativity.
6. Highlight the main objects of scientific and technical creativity.
7. What areas of research activity exist in higher educational institutions?
8. Describe the organizational structure of research activities in higher educational institutions.
9. Describe the structure of organizational management in research institutes.
10. Describe scientific research.
11. Describe the system of scientific research work of students. 6. What forms of scientific research exist?
12. Name the sequence of research stages.
13. Name the processes of studying and learning about the object of research.
14. Name the forms of scientific presentation of research materials.

LECTURE OUTLINE 2

2.1 Concept of creative personality

Creative person, creative person, creator - these words are very often used not only in the scientific environment, in the educational process, but also in everyday vocabulary.

The concept of "creative personality" can be classified as phenomenal, unusual, exceptional.

In everyday life, in society, in education, a creative personality is simply understood as a person who can successfully solve original, non-standard (creative) tasks, knows how to express or generate new ideas, produce new technical or organizational solutions.

From a scientific point of view, the concept of "creative personality" is quite complex due to the breadth of the problem itself and the inadequacy of its development in the fields of psychology and philosophy, cybernetics and neurolinguistics, and the very process of creativity.

A creative personality has a large set of properties. The main element of creativity is the art of multi-criteria optimization, choosing a useful solution [1-3].

The peak of creative abilities occurs in a person at the age of 13-15. In these years, it is important for a person to choose a worthy goal. It must have a plan and program for its achievement, great efficiency, courage and effectiveness.

The first quality needed by an inventor is self-confidence, self-confidence in success and determination to achieve it, which sometimes comes to the fore.

Another feature of a creative personality is the ability to take risks.

It follows from the fact that a person who has a large number of ideas in his head must have the courage to publicly express them, defend and defend them, put forward guesses and hypotheses. It has been scientifically confirmed that a person has two types of thinking - conscious-logical and intuitive-practical.

In the real creative activity of a person, both types of thinking interact in a dialectical unity, their self-separation is conditional, in fact they do not exist separately in a mentally healthy person.

Human intuition is not a miracle, but the result of accumulated experience, diverse and abundant practice.

Solutions offered by intuition only seem unexpected, but in essence they are a complex result of long-standing mental work and deep considerations.

Subconscious activity is much richer and more effective than conscious-logical activity, because it is a superstructure on the common human experience of previous generations.

However, it is possible and necessary to manage the processes of technical creativity.

2.2 Properties of a creative personality

The gifts of creative abilities, from bright and great talents to the most modest, are characteristic of every normal person, every child and student. You just need to be able to find and reveal them, and then develop them.

Since the essence of the creative process is the same for all people, the difference in the manifestation of individual talent should be sought in his personal psychological characteristics, in the environment where the child lives and studies, in the time, content and methods of his involvement in creative activity.

Every single person is talented, intelligent, original and interesting in his own way.

A creative personality is characterized by a large set of properties, each of which determines not only the level of creative potential, but also the pace of its growth over time.

A qualitative generalization of the set of properties of a creative personality by ten main components is shown in the work [4, 5] in the form

$$T = [Z + Z_c] \cdot [(D + C + B)^{H_c \cdot E} + \log C_k] \cdot \sqrt{P \cdot F}, \qquad (2.1)$$

where T – generalized (summary) level of creative personality (T → T_y);

Z – the amount of knowledge a person has;

Z_C – a person's ability to self-educate and restore knowledge;

D – curiosity that is not rewarded, the desire to acquire new knowledge;

C – observation, the ability to perceive the world as a whole without dividing it into important and "trifles";

B – imagination and the ability to generate ideas;

H_C – persistence, tenacity in overcoming difficulties and obstacles in the search for something new;

E – enthusiasm, desire for creativity;

C_k – skepticism, a critical attitude to hypotheses, ideas, theories, a desire to verify or clarify them;

P – memory, the amount of knowledge that a person possesses without referring to books, notes (P → P_y);

F – the state of physical health, which ensures the intellectual activity of the individual.

The work [5] gives the formula (2.1) of L.I. Filipov, supplemented by a number of properties of human intelligence.

To find the specified creative personality Ty, it is suggested to multiply the expression (2.1) by (1–a), so

$$T_y = T \cdot (1 - \alpha), \qquad (2.2)$$

where α – vector of inertia of human thinking, which for different people numerically ranges from 0 to one ($0 \le \alpha \le 1$).

When a person lacks inertia α = 0 multiplier (1–α) disappears, and Filippov's formula (2.2) does not need correction.

At α = 1, the "inertia vector" completely controls a person's personality. He is completely under the power of other people's opinions and stereotypes, and his creative activity completely disappears.

A characteristic feature of a creative personality is great diligence, especially in the field of science that interests him. Any creative person in his activity, first of all, relies on knowledge of physical, chemical, thermal, biological, technical, social and other phenomena and processes, which he draws from books, magazines, reference books, dictionaries, the Internet and television.

Talented people - children, students, engineers - are certainly exceptional.

A creatively gifted person is distinguished by a strict attitude and high demands on himself, on the correctness and truth of anything. It is never satisfied with approximate information, but strives to deepen knowledge, get to primary sources, discover the opinion of experts, find out what it is based on, get to the essence of a subject or phenomenon.

The ability to focus one's attention on some problem, some subject or phenomenon is one of the most important conditions for success, including creative activity.

A negative role in solving creative problems is played by the psychological inertia of thinking, the desire to act in accordance with past experience and knowledge, to follow a traditional path.

Psychological history is often associated with spatio-temporal representations of the object and highly specialized terminology.

The greatest success in science is achieved by someone who possesses one specialty and applies it in another field.

Fundamentally important inventions are made by people who are often new to the field. So, the steam engine was invented by watchmaker James Watt, the jeweler and artist Fulton invented the steamboat, and the telephone was invented by Graeme Bell, a teacher of the deaf and dumb [6-8].

2.3 Teaching technical creativity and creative self-awareness of the individual

The theory of teaching creative self-development is based on the fundamental law of the phase transition of development into creative self-development of an individual, discovered by Andreev [1-3] theoretically and experimentally.

This law was discovered on the basis of studying the biographies of creative and competitive personalities.

Creative self-development, being a complex multidimensional phenomenon, has five basic system-forming components: self-knowledge, creative self-realization, self-management, self-improvement, and creative self-development.

All of them act as specific types of human activity that can and should be purposefully taught.

The essence of the law of the basic transition of development into the creative self-development of an individual is as follows. Personality development, being deformed by external and internal factors and conditions, at a certain stage of life, in the process of positive quantitative and qualitative changes, may at some stage pass into the phase of conscious, purposeful, mostly internally determined activity and transform into creative self-development of the individual.

The activation and intensification of the processes of the transition of development to the creative self-development of the individual is the purposeful mastering of the methodology and technology of self-knowledge, creative self-determination, self-management, self-improvement and creative self-realization.

Guaranteed quality of education and the transition to self-education is achieved when learning transitions into self-education, upbringing into self-education, and personality from the state of development to the phase of creative self-development.

Any kind of creativity requires joint work of mind, heart and hands. The importance of the ability to "think with your hands" is underestimated by many in the hope that you can invent and make something new and useful through abstract reasoning.

Nowadays, this is possible only in the field of "pure" mathematics and logic.

When developing new technical objects, you have to deal with the production of different versions of prototypes and prototypes, and carry out their debugging, testing and proofing literally by hand.

1. Deepening self-knowledge:

application of test tasks and special test tasks that reveal the current and potential level of development of knowledge, skills and especially creative abilities and other personal qualities of students;

encouraging students to creative reflection, to understand their strengths and weaknesses, strong and weak qualities; encouraging students to identify and find their own mistakes, analyze and understand them;

dialogue with the student regarding his strengths and weaknesses; creation of situations of success in which the student would really realize the potential level of his abilities;

setting tasks for self-assessment of students' performance.

2. Creative self-determination:

profiling, differentiation and individualization of education;

providing students with tasks and assignments to choose from;

giving students the right to choose optional subjects, clubs, sections and other forms of activity organization, where they could show themselves as much as possible;

organization of educational, creative and other activities of students taking into account their interests and inclinations;

learning the ability to make decisions, to master techniques when choosing priority types of activities;

conversations with students about their professional choice, professional future;

engaging students in activities that correspond to their inclinations and professional interests.

3. Increasing the effectiveness of self-management and self-organization:

teaching purposefulness, planning various types of activities;

learning the ability to make optimal decisions; adjusting your plans, programs;

self-analysis, self-report on the results of the day, week, month, year from the point of view of advancement in self-development;

showing, studying the best examples of self-management;

gradual complication of tasks, tasks, motivation to study, work at the limit of one's abilities;

encouraging the student to dialogue about his "I"-concept, "I"-real and "I"-ideal.

4. Self-improvement:

critical, unbiased analysis, self-evaluation of the completed task, the solved problem, the completed life path;

correction of mistakes;

the ratio "I"-ideal and "I"-real, their comparison;

identification, self-diagnosis of one's strong and weak qualities;

development of a program of self-improvement, changes, self-improvement for a year, month, week in advance;

timing of time, its distribution during the day, taking this into account - a more rational use of time.

5. Creative self-realization:

periodic organization of educational, creative and other activities of students at the limit of their strength and abilities;

gradual increase in difficulties, complexity, problematic nature of tasks and assignments;

clear limitation of terms (time) for the completion of tasks, tasks;

special training of students in mobilization and relaxation;

organization of contests, competitions, Olympiads, exhibitions of students' creative achievements;

showing the importance of types of creative activity in which a person seeks to realize himself as much as possible;

creation of success situations for students;

praise, encouragement of the student in the case of his special creative achievements.

6. Sustainability of positive changes.

The essence of sustainable positive changes lies in their component composition (self-knowledge, creative self-determination, self-governance, self-improvement and creative self-realization) and consists in the fact that the process of motivational changes in one of the named components requires positive changes in others.

In this regard, from the point of view of pedagogical activity, it is important to stimulate positive changes in at least one of the components.

This will lead, as in a chain reaction, to positive changes in all components.

Naturally, for pedagogical stimulation of creative self-development, and even more so for teaching creative self-development, fundamentally new textbooks, new teaching methods and technologies are needed.

The conditions formulated by the famous physiologist Vvedensky can be cited as a recommendation for ensuring high performance. Before his death, having already become a world celebrity, he said: "All my life has passed, one might say, in the company of the neuromuscular drug frog."

In the fundamental course of animal and human physiology [9, 10], Vvedenskyi formulated the conditions for the productivity of mental work in one of the special chapters. This is a lesson given by a hard worker of science who knew how to work as an artist works – without noticing fatigue.

Vvedensky believed that people get tired not because they work a lot, but because they work poorly.

The first condition necessary to ensure spiritual efficiency is that any work must be entered gradually, without expending strength, but developing pressure gradually.

The second condition for the fruitfulness of mental work is the uniformity and rhythm of work. Even in the minds of the ancients, work, patience in work and disciplined uniformity of work were considered a virtue, almost identical to the only reliable basis of healthy thinking.

The third condition for successful work is consistency and systematicity of activity.

The fourth condition, which is very important for the fruitfulness of mental work, is a faithful and regular alternation of work and rest. Untimely rest leads to overfatigue, which ultimately reduces a person's work capacity. Rest does not imply the obligatory complete inactivity of a person.

It can be carried out by a simple change of work - by shifting attention to a new field of activity.

Immanuel Kant is considered to be an example of the most efficient distribution of time and enormous mental capacity: according to him, the residents of Königsberg defined time. Lev Mykolayovych Tolstoy maintained a high capacity for work until almost the last years of his life thanks to the faithfulness and systematic organization of his work. This explains the definition that Newton gave when he was asked what, in his opinion, genius is: "Genius is work."

A genius is first of all a brilliant worker, then a person with the highest ability to concentrate.

M. Vvedensky considered the fifth condition of work to be a more or less favorable attitude of society to this form of mental work.

It is obvious that the social environment that surrounded Lomonosov, although he had a vague feeling that there was a great man in front of him, was very far from understanding and appreciating her. During his life, Lomonosov had to spend a lot of energy unproductively in order to achieve the opportunity to work on the problems that bothered him.

Control questions and tasks for independent solution

1. Explain the concept of "creative personality".
2. What are the main types of human thinking?
3. Define the characteristic features of a creative personality.
4. Define the factors of human inertia in solving creative problems.
5. What defines creative self-development?
6. Illustrate with a diagram the main principles of the personality transition to creative self-development.

LECTURE OUTLINE 3

3.1 System engineering of technical contradictions

The need to develop principles for managing the process of creating technical objects, technologies, technical processes, machines, and other determined by many reasons: economic, social, environmental, safety requirements and others.

Human activity is a system, before the transformation of something new into technology (the creative aspect of technical activity) is in the field of research of both scientists, the creators of technology themselves - engineers, designers, inventors, as well as philosophers, sociologists, psychologists.

The ever-growing needs of mankind are the root cause and driving force of the continuous development of technology, improvement and creation of new technical objects.

The driving force of the creative process is the system technique of contradictions in the system "man - technical object - environment". Contradictions can arise both between the elements of this system and within the technical object itself. These phenomena are objective in nature, they are explained by the dialectical interdependence of phenomena and objects of "natural" and "artificial" origin.

Defined requirements for the development object are formed. Requirements are a form of expressing a goal in the process of activity. Requirements can be objective and subjective in nature.

The result of solving each contradiction is a new technical object (or system of objects).

This new object, thus, is the result of identifying contradictions, setting a problem and solving it, that is, a purposeful creative activity.

Some authors specifically consider the systematics of contradictions in technical creativity - the sources of the creative process itself.

Thus, Altshuller [5] singles out three of their groups: administrative (“something needs to be done, but how to do it is unknown”) contradiction, technical (“conflict between parts and properties of the system”) and physical (which reflects the “physical essence of a technical contradiction”) .

Without going specifically into the completeness of the groups of contradictions in technology provided by these and other authors [6-10], we note that the regularities of such a complex phenomenon, which is presented before us by technical creativity, can be revealed first of all during its analysis - as a system of contradictory relations in activity.

Special, or more precisely, the main importance in this kind of view should be the relations that arise between the actor himself (the subject of creativity) and the objective circumstances under which this activity takes place (the object of creativity).

Subject-object relations act as a leading characteristic of technical activity: they reveal, "enlighten" the dominant in the orientations of a person as an actor, while determining the essence and meaning of contacts arising between a person and the environment.

At the same time, some initial contact ("meeting", "conflict") between the actor and objective circumstances can be detected, which appears as a problem in technical activity and technical creativity.

The physical contradiction is represented as follows: element A must perform action F1 (have some property) in order for function C1 to be performed, but element A must also perform action F2 (have the opposite property) in order for function C2 to be performed.

For example, an element must be a conductor in order to pass electric current in one direction and must be a dielectric in order not to pass electric current in another direction.

There are six main sources of technical contradictions between:

the entire structural design or system and part of the components, elements and systems of a technical object, which reflect the strength and manufacturability of the structures, which determine its reliability, durability and other aspects;

technical object and those who produced it, due to a conflict between the object of work and the production worker;

a technical object and a person who manages this object (operator) or operates it (user). Conflict situations arise due to a change in the operating conditions of the object, changed requirements for its safety, efficiency, ergonomics, technological process;

a technical facility and production environment, one of the components of the environment, i.e. compliance with the norms of creating ecologically clean technical systems and technologies (Fig. 3.2, (see Presentation to the lecture 3);

the content and form of the components of the use of a technical object, the essence of which is the dialectical relationship of individual components.

A technical contradiction arises and manifests itself at all stages of the life cycle of a technical object: development of an idea and design, manufacture and adjustment, operation and modernization.

A technical contradiction can be revealed, first of all, when analyzing it as a system of contradictory relations in activity.

Those properties of the object that must be changed in accordance with new or specified requirements are analyzed, that is, the relations that arise between the actor himself (the subject of creativity) and the objective circumstances under which this activity takes place (object object of creativity).

Subjective-objective creative relations act as a leading characteristic of technical activity: they reveal a person as an actor, and at the same time determine the essence and meaning of the contacts that arise between a person and the environment. At the same time, the original relations between the actor and the objective circumstances are revealed, which appear as a problem in technical creativity.

The real environment includes all sources of external influences in the immediate environment of the transformation process.

The real environment includes the geosphere (land and water), biosphere (people, animals, plants), technosphere (technical means), atmosphere and climate (weather), which in most cases cannot be determined precisely.

Different ecosystems can be built from the geo-, bio- and atmosphere. In them, the processes of transformation of matter, energy and information necessary for life take place within the limits of defined relationships.

When developing and implementing any technical solutions, the balance of these systems should not be disturbed.

The objective side of technical activity includes the natural and social conditions for the development of this activity, it also includes everything that a person has already created and uses in his life.

The objective is what "opposes" a person as a subject of creativity in the process of his activity.

The subjective side is the active position of a person in relation to the existing objective conditions.

The relationship between the objective and subjective sides forms a definite, often rather stable, contradiction during various periods of activity; this contradiction determines the nature and form of achieving the desired result.

The rupture of subject-object ties destroys the activity itself as productive, creative, and in this case the activity turns into a reproductive one or is generally disrupted, "ceases" its "existence" as a process of forming some specific object.

The analysis of subject-object relations is inseparable from the analysis of other aspects of activity, among which a special role belongs to the ratio of goals and means: the goal organically reflects the essence of human actions, their social and cultural content, their personal content, reveals the orientations and nature of ties in activity, forms of their self-organization.

Real or potentially real means should correspond to the goals that a person sets for himself.

Turning to the category of goals and means in the analysis of technical creativity allows us to approach its study in a multifaceted way - on the one hand, in terms of considering the goal of the direction of the human "I" in this world, and on the other - the possibility of realizing these intentions.

The goal is determined by the contradiction of reality itself: the relationship of the goal is the relationship of contradictions.

The absence in material activity of what is the essence of the goal is the main contradiction, it is it that acts as a direct source of activity.

The goal also manifests itself as a powerful system-forming factor in activity, as a principle of integration of various human actions into a certain sequence, system, that is, into the activity itself. It, being a reflection of a person's position to both the past and the future, determines the state of activity at the moment, forming ("building") the future. The goal connects the past, present and future into a certain whole.

The genetic process of setting goals in the process of technical activity is a particularly important aspect of creativity.

Success depends on the dynamics of goal orientation - first of all.

In order to identify the main principles of managing technical creativity, it is most expedient to consider the moments of origin and formation of a specific creative result.

Centuries of socially useful practice of mankind has accumulated an infinitely large number of techniques for eliminating technical contradictions, which are impossible to know in full.

In some sources, an attempt to classify many typical techniques by dividing them into larger groups based on some common features is visible.

However, the set of such signs is random and quite subjective. A more rigorous approach to the classification of typical techniques for solving technical contradictions is proposed in works [1, 2, 4, 5], which take into account three components of the substance of technical objects as classification features: matter, energy, and information.

With this approach, five groups can be distinguished from the multitude of actually existing and possible typical techniques for transforming the components of the substance of technical objects (MTC):

a) MST – methods of substance transformation, which, in turn, are divided into:

– MTFM – methods of transforming the form of matter;

– MTCM – methods of transforming the composition of matter;

b) TEC – techniques of energy conversion;

c) ITT – information transformation techniques;

d) CEIMT – complex energy-information-material techniques based on the use of new technologies and methods of manufacturing, transportation and application of technical objects.

From the known set of typical measures for solving technical contradictions, heuristic and algorithmic measures are the most appropriate.

Algorithms and typical techniques for eliminating technical contradictions developed by Altshuller, a fund of physical effects and phenomena, as well as generalized heuristic algorithms for finding new technical solutions developed by the author [7] are presented in works [4, 6], which represent a powerful information apparatus that significantly increases the speed and probability of successfully solving technical and inventive problems, increases the level of their solution.

3.2 Needs, consumer functions and criteria for the development of technical objects

Historical experience proves that in the world of technology, everything is done to meet the needs of people and society as a whole.

If there was no need for a technical facility, it would not have been created. Conversely, if there is a need for it, it will certainly be created.

The time to create an object will be the shortest if the need it fulfills is more acute and socially significant.

The difference between a need and the consumer function of a technical object is only that the concept of "need" denies a person's interest in its implementation, and the concept of "consumer function" reflects the action of a technical object that realizes this need.

The description of the need (P) must contain at least three components of information

$$P = f(A, B, C), \qquad (3.1)$$

wehere A – actions that lead to the satisfaction of the need in which interest is expressed;

B – the object or subject of technological processing to which action A is directed;

C – the presence of conditions or restrictions under which this action is implemented.

For example, the need for a bus is to transport (A) people (B) on roads (C).

Structure and actions form the basis of the structural and logical functions of needs.

Structure can be seen as a logical function of action, and action as a logical function of need.

The need is determined by specific criteria, the actions by systems, and the structure by constructions.

The object of engineering activity is a defined goal, the path to which is marked by various criteria.

The system engineering model is based on the dialectical connection of science – technology – production [8].

The goals of creating needs are determined by the requirements of the object's immediate and indirect surroundings.

For a visual representation and systematization of goals, it is convenient to use a graph of goals.

All environments are divided into levels depending on their scale.

On the first level is placed the sphere covering the interests of all humanity; on the second - the interests of the state; then - spheres of interests of the industry, enterprise, project organization, department and, finally, the sphere of personal interests.

Each level has its own goals, which are subordinate to the goals of a higher level. A graph whose vertices denote goals, and whose arcs represent their relationships, is a graph of goals [9, 10, 11].

Design goals at each level of public interest are unequal in their importance. Some of them must be achieved, others are desirable. The role of development criteria is especially important in the development of new products, when designers and inventors seek to surpass the level of the world's best achievements.

The entire set of technology development criteria is usually divided into four main groups:

functional, characterizing the performance indicators of the object's function;

technological, reflecting the possibility and complexity of manufacturing a technical object;

economic, which determine the economic expediency of implementing functions with the help of the considered technical object;

anthropological and ecological, related to the assessment of the impact on a person of harmful and positive factors on the part of the created technical object.

The classification of the systematics of the development of technical objects, allows the developer of new equipment to formulate and describe a set of development criteria for the required class of technical objects from a large number of technical object parameters.

Only those that satisfy the following requirements are accepted as development criteria:

be measurable, i.e. quantified;

to be comparable, that is, to have units of measurement that allow comparing technical objects of different times and countries;

to be prioritized, primarily those that characterize the efficiency of the technical object, logically minimal and independent, that is, they cannot be logically separated from other criteria or they cannot be their direct consequence.

The set of criteria is regulated by the state quality standard [10-12].

According to which quality indicators are divided into 10 groups destination; reliability; economical use of materials and energy; ergonomic and aesthetic; indicators of manufacturability, standardization, unification and safety; patent law; economic

It is obvious that the strategy of choosing quality indicators for such a complex, expensive, time-consuming technical object of mass application, as a passenger car, is within the power of only a large creative team that specializes in this problem and has appropriate banks of information, not only technical and economic, but also opportunistic nature.

This example is given only to show the great significance, multidimensionality and variability of the justification and selection of quality indicators when developing new or improving known technical objects [1-3].

3.3 The role of the team and the individual in scientific and technical creativity

Scientific and technical creativity is now a field of collective activity. Collectives should be a system that promotes creativity and does not exclude individual initiative.

In such conditions, the socio-psychological and organizational problems of the collective's primary creativity come to the fore.

To manage means to anticipate, organize, coordinate, control.

The main functions of the manager are: choosing a goal, drawing up an organizational plan, selecting and placing personnel, making decisions, creating a creative environment in the team.

It is contraindicated for him to play the role of critic and executor.

He should mainly deal with the generation of ideas and the organization of the team's activities, connect the creative group with society, science with practice, and contribute to the realization of common goals.

The manager is expected, first of all, to be able to inspire and encourage others to be creative.

We know well from practice that the development of new technologies, technical and especially economic methods is opposed by the administrative apparatus, whose bureaucratized elements are anti-innovative by nature.

Scientific and pedagogical teams do not always create a psychological climate and all the conditions for creative activity, democracy, equal power with equal competence, a favorable attitude of society to intellectual work.

The role of the human factor in increasing the efficiency of scientific work will be considered on the basis of the use of work materials [12].

Once under Korolev, a dispute arose about how to increase the productivity of scientific workers. Speaking about the shortcomings in this field, Serhiy Pavlovich noted three reasons:

it is necessary to bring the number of scientific and technical personnel in line with the available number of scientific employees as soon as possible, so that the ratio is equal to 1:3;

slow implementation of scientific developments in production;

imperfect forms and methods of planning and funding of scientific research and development.

Sometimes there are cases of a kind of inquisitiveness, arrogance or snobbery and "degree swagger", contemptuous attitude of famous scientists to scientists of "lesser caliber", theorists to practitioners, and other

At the same time, one party receives satisfaction from the feeling of superiority earned by past merits, the other party feels humiliated. Naturally, this does not contribute to the emergence of a creative atmosphere and harms science.

The creative potential of researchers is one of the most important resources of modern society.

But in our time, a peculiar relationship has developed between the researcher and society. The time of lone scientists has irretrievably passed, now the researcher works in a team and his position is determined by a complex system of official relations.

One of the most important problems that arose in connection with the collectivization of scientific work is the choice of the most effective management system for creative teams.

Most people think that the best way to organize creative work is to get good scientists together and leave them alone.

But, as studies have shown, almost always a major discovery or invention took place precisely in such conditions, when the author felt the urgent need to put forward a new idea to solve a practically important problem.

And a necessary condition for effective creative activity is the "ultimatum" set before the scientist or inventor, which forces him to either propose a new idea or show his inability.

It turns out that creativity is not only not hindered, but also facilitated by strict control over the purpose of research.

It is clear that what has been stated has nothing to do with the attempt of some scientific administrators to establish petty control over the activities of researchers.

When the strict implementation of organizational regulations and compliance with discipline become an end in itself, not only creative activity disappears - the productivity of any type of activity decreases.

Correctly posing a problem, forcing a scientist or an inventor to strain his creative abilities, is a difficult art.

A very common mistake of science management bodies is that the scientist is not presented with the whole problem, but only a part of it.

This is done, as a rule, with good intentions - it is believed that giving the researcher only the necessary information saves his time and effort. But in fact, such a "cutting down" of the problem, usually carried out within the framework of traditional thinking, consists in overcoming these frameworks.

In organizations built according to the hierarchical principle, "cutting down" the problem occurs automatically.

Descending from level to level, the problem is inevitably fragmented and reaches individual performers in the form of partial, unrelated tasks and has a sharp negative impact on the creative activity of all employees.

Now it is recognized that it is appropriate to go to some additional costs of means and time, but to bring the problem in full to all employees, regardless of their official status.

In particular, in some US firms, lists of problems that could become the subject of research are published in the form of a brochure every year, and such a brochure is distributed to every employee of the laboratory.

Personal contacts of researchers with consumers of future work results are also encouraged: this allows not only to better see the whole problem as a whole, but also to get rid of possible distortions of information that are inevitable when transmitted along a multi-stage chain of different administrative levels.

The psychological climate in the team is created by many factors. Here it is appropriate to consider only one of them, namely: such a state that would cultivate self-confidence in a creative personality, which would sometimes reach self-confidence.

Sometimes we can ignore this or that life's inconvenience for a long time, but in the end, patience suddenly comes to an end, and together we spit out all the accumulated irritation, even if the last dose of trouble was microscopic.

It is not for nothing that they say about the drop that can overflow the cup of patience... This is a typical threshold phenomenon, when up to a certain limit the action does not noticeably affect the system, and then suddenly causes the strongest shocks in it.

In short: quantitative changes accumulate and lead to a new quality - this is the dialectical law of the transition of quantity into quality.

But in nature, there are also no absolutely precise boundaries of the transition of quantity into quality.

The specificity of creativity leads to the fact that people constantly appear in the primary team who occupy different "role" positions when solving problems.

One of the employees assumes the role of a generator of ideas, another - a critic, the third performs the organizational part, the fourth - the executive part of the work, the fifth deals with implementation, and other

In practice, one employee often has to perform several roles.

A role structure is inherent in any group that is united by a common goal. In such collectives, it is necessary to adhere to the principle of compatibility (physiological, psychological, intellectual, moral), that is, to create such a style of mutual relations in which no life collisions and scientific clashes would lead to destabilization of work.

However, the activity of a scientific team almost never occurs without creative conflicts: real success can be achieved only as a result of the struggle of ideas.

But it often happens that a fruitful struggle of ideas turns into an everyday quarrel. At the same time, it turns out that interpersonal contradictions can be extinguished until they reach a certain critical value.

If this line is crossed, then even a small effort of unkindness can lead the team to complete disintegration.

It is important to note that different people have different thresholds of irritability, above which they become unmanageable. At the same time, particularly unbalanced individuals can serve as "starters" that shake the team and bring it to a critical threshold.

Identifying such people, following them and neutralizing them in a timely manner is the most important task of the manager and the entire team as a whole.

All this is important to take into account when forming new scientific centers. Incorrectly set size of the center, as well as selection of personnel on formal grounds, can lead to the fact that the concentration of key people does not reach the maximum value and capable scientists will not try to work in this center.

On the contrary, special efforts to attract leading scientists will begin to quickly pay off when the threshold value is reached.

It is believed that the number of employees in the creative team should not exceed 20 people. Moreover, a group of 15 scientists works, as a rule, much more productively than 5 groups of three people and is only half inferior to a group of 45-50 people.

On the other hand, as the size of the group increases, so does the pool of talent and resources suitable for solving technical problems.

In order for each employee to work with maximum efficiency, it is necessary to strictly observe the principle of scientific equality.

Threshold phenomena must also be taken into account when planning the individual work of scientists.

Every major discovery is a marginal phenomenon in the understanding of this or that problem.

Society rewards those scientists who were the first to "cross the threshold" with honors, prizes and titles, but at the same time, it does not take into account who and how much effort they spent in the pre-threshold area.

And it can also happen that others did all the preparatory work, and the author of the discovery only had to formulate it!

Even Einstein himself doubted the fairness of such work, noting that the activity of each scientist is so closely connected with the work of his predecessors and contemporaries that it should rather be considered a coincidence that the decisive step was taken by one person and not another.

A wise manager can dare to create such a psychological climate in the team, when a creative individual gains enough confidence to take a decisive step across the threshold.

After all, in the call to cultivate self-confidence, one can see an attack on the most sacred rule of collectivism, which requires modesty. In the same way, knowing the truth sometimes requires great courage from the researcher: "If modesty is a characteristic feature of research, then it is more a sign of fearing the truth than fearing lies.

Modesty is a tool that restrains my every step forward. It is the researcher's fear of conclusions given from above, it is a preventive measure against the truth.

Unfortunately, the tendency to criticize other people's ideas is probably an innate human trait. Figuratively speaking, a new idea (of course, someone else's) affects a person in the same way as a foreign protein introduced into the body - it causes an immune reaction and tension of all intellectual (well, if only their) forces against the new idea.

Having met with a group of critics, who often have much more erudition and authority than the author himself, the idea dies.

This is where the leader should come to the podium. His direct duty, which should be written in the job description, is to protect the creative personality from excessive criticism of colleagues.

This function of the leader is so important that many researchers of scientific creativity tend to consider it crucial.

Undoubtedly, the situation of the manager who protected the author of a new idea may turn out to be delicate, because the idea may be wrong. Therefore, the manager should warn his employees from the very beginning that he and the author have the right to make mistakes, because there is no creativity without mistakes.

But only the one who does not produce anything fundamentally new, but is content with uncreative work, is not mistaken.

It will not be superfluous to recall the statistics: for every result implemented in production, there are 8 patents, 98 technically implemented solutions and 540 ideas!

Studying the activities of the most creatively gifted researchers shows that the right to make mistakes pays off: for them, a mistake or even several of them serve only as a stepping stone to great success.

In this sense, a mistake is a kind of ultimatum that mobilizes creative forces. Of course, for the error to play a positive role, the researcher must have a certain courage and confidence in his abilities.

After the idea is generally accepted, it is necessary to discuss it with a more or less wide circle of people.

Based on practical experience, scientists made two interesting conclusions:

1) multiple discussions and debates as a method of separating bad ideas from good ones lead to the elimination of all ideas;

2) the more people participate in discussions and debates, the less chance the idea has to survive.

Apparently, the subjective factor will play a decisive role in the evaluation of scientific ideas, which due to their novelty are not amenable to logical analysis, and the demand for "democratization" of the evaluation cannot be considered appropriate.

Democracy presupposes equal power with equal competence: in science, one person can be more competent and far-sighted than a hundred colleagues.

The best way to ensure the maximum probability of a positive evaluation of a fruitful idea is to have the most visionary employee in the position of "chief evaluator" of ideas. Voting is not acceptable here.

Finally, as information for reflection, it can be reported that according to the calculations of the famous American scientist D. Price, one hundred researchers publish scientific products only 3.3 times more than one researcher.

That is, the increase in the cost of research is proportional to the square of the number of scientists participating in it, and the effectiveness of research is proportional to the square root of this number.

It is necessary to find ways to intensify real scientific creativity, and not simple engineering work, although this is also necessary.

Control questions and tasks for independent solution

1. What is the driving force of the creative process?
2. Name the main sources of creative contradictions.
3. What are the typical techniques for solving technical contradictions?
4. What is the difference between the need and the consumer function of a technical object?
5. What belongs to the direct and indirect environment of the object?
6. Give an image of the graph of the goals of the development of technical systems oriented to the interests of society.
7. Show a diagram of the system engineering classification of the development of technical objects.
8. Explain the role of administrative and human factors in increasing the efficiency of scientific work.

LECTURE OUTLINE 4

4.1 The concept and composition of technical objects and systems, technologies and their interaction with the environment

Technology is a whole world of inanimate nature. It surrounds us in production, on the street, in the field, at home, in space, the number of technical objects theoretically approaches infinity.

Our future depends on the efficiency of technology, technology is one of the keys to progress.

The concepts of "technical object" and "technical system" are synonyms because they reflect the same concept, but with different nuances when used and described [1-12].

The concept of "technical object" is broader, since "technical systems" are only its variety.

The object is mainly called technical in those cases when it is discussed in general, without any structural, functional and constructive specification, while the term "technical system" is used when discussing its internal content, when studying, analyzing, synthesis and construction.

A technical system is a defined collection of orderly interconnected elements that have aggregate properties that not only summarize the properties of the elements included in its structure, but also other qualitatively new properties that are not characteristic of system-forming elements, for example, a car has movement properties, while none of its individual elements (body, chassis, engine, and other) have such properties.

It is important to keep in mind that any technical system consists of a number of structural elements (links, blocks, nodes, aggregates), called "subsystems", the number of which, in general, can be equal to "N".

At the same time, most technical systems also have supersystems - technical objects of a higher structural level, which include them as functional elements.

The supersystem can include from two to "M" technical systems. For example, if the electric starter for starting the engine is considered as a "technical system", then the engine itself can be considered as a supersystem, and the component structural elements of the electric motor (shaft, bearings, pole windings) - subsystems.

Any technical object is in a defined interaction with the environment.

It performs certain functions (operations) from the transformation of matter (objects of living and non-living nature), energy or information signals.

8Processing of matter, energy or signals with the help of technical objects is carried out by performing a number of technological operations performed one after the other in a defined sequence. Technology means a method, method or program for converting matter, energy or information signals from a given initial state to a given final state using appropriate technical systems (objects).

The interaction of a technical object with the surrounding living and non-living environment can take place through various communication channels, which should be divided into two groups.

The first group includes flows of matter, energy and information signals transferred from the environment to the technical object. These include: AT – functionally determined (or controlling) input influences, input flows into implemented physical operations; AB - forced (or disturbing) input influences: temperature, humidity, dust, and other

The second group of communication flows are those transmitted from the considered technical object to the environment. These include: ST – functionally determined (or regulated, controlled) output influences, output flows of physical operations implemented in the object; SV – forced (disturbing) initial influences in the form of electromagnetic fields, pollution of water, atmosphere, land, and other

4.2 Stages of development of technical objects

The life cycle of a machine includes the stages of research, design and proofing, serial production (production), operation and decommissioning.

Its calculation is carried out according to the formula [10-12]

$$T_{ЦМ} = T_{ПР} + T_{ВИГ} + T_{С}, \qquad (4.1)$$

wehere $T_{ПР}$ – the calendar period from the beginning of machine development to acceptance tests;

$T_{ВИГ}$ – duration of machine manufacturing, including production preparation;

$T_{С}$ – service life of the machine.

Graphically, the development cycle of a technical system can be represented graphically by a broken curve, which illustrates how the characteristics (g) of the system (productivity, energy consumption, power, speed, and other) change over time (t) and other).

In different systems, this curve has its own individual characteristics.

The technical level of the created mock-up and experimental samples does not always (for technical, economic and other reasons) correspond to the required technical level of D.

Unreliable B and D quality level machines can often be produced for the same reasons.

After the decision on improvement is made, the created system A (site 1) can quickly develop to level G (site 2) and above to the economically justified requirements of D.

In section 3, the rate of development of the system decreases, it exhausts its potential and begins to age.

In the future, the system morally becomes obsolete or degrades (curve 5) or retains the achieved indicators for a long time (section 4).

At stage 4, the object can be modernized or replaced by a fundamentally new B system.

It is obvious that in the process of development of a technical object, the transition from one stage to another in zone E occurs when the physical or intellectual capabilities of a person to further increase the current criteria of reliability, energy consumption and productivity are exhausted.

Then the quality of the object can be improved only with the implementation of other scientific and technical developments.

Development processes of technical objects (TO) of the same functional purpose and technology in general represent objective regularities: technology gradually develops over time in the direction of transferring fundamental labor functions from a person to a technical object.

The entire development cycle of a technical object has 4 stages, which correspond to the four fundamental functions of labor and machines for the processing and production of material products.

4.3 Conditions and processes of development of technical creativity

One of the main components and conditions for the development of creative activity is the inclusion of a human actor (engineer, designer, inventor) in the objective circumstances that determine this activity itself, its emergence and development.

Without inclusion in the objective conditions, no subjective position, proposal, or expectation makes sense.

Every creative act must necessarily be preceded by a certain process of familiarizing a person with specific objects, their advantages and disadvantages, working conditions from predictive positions.

On the basis of this analysis of shortcomings and from prognostic positions, a requirement for the development subject is formed. A requirement is a form of expression of the purpose and process of activity. Requirements can be objective and subjective in nature.

The concept of "inclusion" is compared with such concepts as "interest", "understanding", "comprehension", which characterize the creative contact between the subject and the object.

The process of including a person in an active situation comes down to: determining the requirements and resources in a specific situation; formation of the actor's position regarding objective conditions (requirements and resources).

But no matter how carefully the shortcomings of existing technical objects are thought out (in terms of identifying requirements for new ones), it is not possible to achieve an optimal result until adequate means of achieving these requirements are determined.

The formed position of the actor in relation to objective conditions speaks of the establishment of "subject-object" relations, the beginning of creative contact, the actor's conscious view of the surrounding circumstances. In fact, here the actor determines for himself the inadequacy in solving this or that issue, forms the problem of activity, which he seeks to solve further.

Posing a problem is one of the most difficult and important steps in creativity. It is significant that the increase in the number of different kinds and types of requirements and resources does not particularly change this situation: it opens up an opportunity to present the desired ideal more fully, more fully, but not completely.

In the activity, it is important to achieve their dialectical "fusion". In this merger, the formation of a qualitatively new entity takes place, namely, a creative proposal for achieving the desired solution.

The process of forming a proposal acts as the construction of a technical subject. Schematically, the transition from requirements and resources to the offer, and then to the final decision.

Only through the inclusion of a person in objective conditions as the formation of the "subject-object" relationship can there be:

new technology was created;

the existing technical system has been adjusted and proven;

the content of old technical projects and ideas is clear;

trends in the formation of future, as yet unknown structures are revealed.

Based on the conditions of a person's inclusion in specific circumstances, it becomes clear that the search for specific solutions depends on a person's level of knowledge, his creative search, preferences, and the goals he sets for himself and other people.

In the preparation of the inclusion of a person in the conditions of activity, a special role is played by his mastery of knowledge and practical experience. Here, the development factor of a person's potentially real opportunity to be included in certain specific situations in the future activity and a flexible attitude to the use of emerging circumstances is indicated here.

In the process of research, there is an understanding of the active conditions of the context, the selection of functional and morphological aspects of the subject and the environment. There is a dismemberment of the "object-environment" system into some constituent elements, which makes it possible to reveal the peculiarities of the construction of the object, its specificity, the connection with other parts and with the whole (environment).

Usually, this analysis allows you to identify the shortcomings of previous technical solutions.

The field of research includes the analysis of genetic aspects of the development of close objective conditions of functioning, applied constructive principles and systems.

Inclusion in specific circumstances can be random and purposeful. An accidental inclusion can be decisions as a result of attentiveness, observation of the author-actor.

Case orientation cannot be considered optimal when developing technical objects.

The inclusion, which has the character of a purposeful study of the search for a solution, is aimed at the oriented circumstances of the existing operating conditions, which implies, first of all, the study of the development trends of the technical system and the analysis of precedents for resolving conflicts that arise in it.

Variation, the search for suitable (for the set goals based on the available means) ratio of requirements and resources, the "earning" of new qualities, the identification of unsuccessful solutions and their "sweeping out", the appearance of new combinations of components and their new evaluation - this is the way to find a new result. Such a chain of solution development develops, expands up to a certain limit of saturation, when the desired result begins to be revealed quite precisely and the process of concretization of the solution begins.

Saturation assessment criteria:

a) achievement of the most progressive requirements under the condition

b) objectively realistic use of adequate resources.

Thus, the process of creativity acts as the mastering of objective circumstances in accordance with those goals that a person has set for himself and which were formed (including clarified, corrected) in the process of activity development.

On this path, the principles of managing the process of creative search are determined, in this case it is mainly about subordinating information to human needs.

The transformation of information (construction) is not simply the selection of some possible combinations of resource requirements among themselves, but the construction of a complete organic formation, a new result.

This is a "collapse" of information. The inclusion of a person in the context of activity and the construction of the result are dialectically related to each other in the direction of creative thought.

Inclusion is a person's awareness of the "field" of his possible creative contacts and simultaneous removal of the psychological barrier before making a decision.

Design is the limitation of the scope of the search, and the dominant definition of the development option of a technical subject is decision-making.

Inclusion is entry into the material and spiritual aspects of culture; construction is the formation of a new culture.

The management of technical creativity – more precisely, the processes that lead to its emergence and successful development – is based on two opposing dialectically interdependent tendencies:

internal (subjective), caused by the creative growth of the specialist himself, the improvement of his qualifications, the level of activity when approaching the solution of technical issues, the development of a critical attitude to existing technical solutions, etc.;

external (objective), determined by social relations, organization of an optimal system of professional training and education of a specialist, coordination of technical activities, systematic publication of necessary scientific works, reference books, organization of control over the solution of urgent problems, management of the use of resources.

Both of these trends are necessary - one cannot fully develop without the other.

Control questions and tasks for self-study

1. How do the concepts of "technical object", "technical system" and "industrial production technology" differ?
2. Describe the stages of the life cycle of machines.
3. List the stages of development of technical objects.
4. State the main stages of transfer of fundamental labor functions from a person to a technical object.
5. Describe the concept of "subject - object", "inclusion of a person in specific objective conditions", "requirement for the development of an object".

LECTURE OUTLINE 5

5. Evolutionary ways of creating new technical objects
5.1. Correlation of rates of development of science, technology and production
5.2. Evolution of indicators of development and demand for technical objects
Control questions and tasks for independent work

5.1 Correlation of rates of development of science, technology and production

The laws of development in the technical sphere are the same as in living nature. They have similar life cycles and stages of development.

Improving the quality of machines is achieved either by improving existing models or by creating fundamentally new ones that embody progressive ideas.

Since the emergence of a new type of technical objects, which took place as a result of a jump, its development has followed the path of quantitative changes. However, this can only happen up to a certain limit, when it becomes impossible to further improve quality indicators within the existing species.

From this moment, the emergence of development contradictions acquires a certain character and leads to the appearance of a new type of technical objects that implement more advanced technology.

The goal of the progressive development of technology is to improve any development criterion in the presence of defined socio-economic needs and scientific and technical conditions.

In fig. 5.1 (see Presentation to lecture 5) shows the relations in the macrosystem "society - economy - science and technology", and fig. 5.2 – ratio of development rates of science H, technology T and production B [2].

Mathematically, the development of science over time can be presented as [1-3, 13]

$$H = H_o \cdot e^{kt}, \qquad (5.1)$$

wehere H_0 – achievements of science up to the point of reference;

k – constant;

t – time.

With the development of science, new knowledge appears that allows you to develop new materials, technical solutions and use them to create new technological equipment (technical objects).

New equipment is introduced into production in order to increase its efficiency. From this it is obvious that the rate of development of science should be ahead of the rate of development of technology and production.

As the author [10] recommends, if in the presence of the necessary scientific and technical potential, the transition to a new technical solution or principle of operation provides additional efficiency that significantly exceeds additional intellectual and production costs, then it is worth making a leap to a new technical solution or principle of operation (without exhausting the possibilities of a previous technical solution or principle of action).

This provision should be used in connection with the use of computer technologies of technical creativity, with the help of which it is possible to carry out global, multi-criteria optimization of technical solutions, simultaneously covering all stages of development of technical objects.

Each newly created or improved technical system has an increased level of consumer properties R (or the main useful function) and technical complexity S (increasing the mass of the number of subsystems, the cost of components and manufacturing) compared to its counterpart.

Moreover, the growth of the structural complexity of technical systems occurs according to a non-linear dependence [2]

$$S = k \cdot R^b, \qquad (5.2)$$

wehere k and b – empirical coefficients.

The further contradiction with the indicators S of the created system often goes to the evolutionary process of using new physical principles of creating a technical system, which ensures a sharp reduction of this indicator while further improving the level of the main useful function R.

For example, over the past 50 years, it was possible to reduce the specific weight of diesel engines (kg/horsepower) by 250 times, steam power plants at thermal power plants by 25 times; the dimensions of electronic computing machines decreased by a hundred times, the dimensions of electronic amplifiers decreased by a thousand times and other.

5.2 Evolution of indicators of development and demand for technical objects

The operational principle is often used in the development of new technical systems.

The necessity of iterations follows from the following. When developing a complex technical system, it is impossible to cover all situations at once, so the knowledge turns out to be incomplete, requiring additions, clarifications and comparisons with reality to identify and eliminate omissions.

The necessary completeness of knowledge and understanding is achieved only as a result of a series of iterations.

Any fairly complex technical system, due to the impossibility of tracing all cause-and-effect relationships in the system itself and in the environment, acts as a not entirely deterministic object that requires consideration of probabilistic facts.

Hence, when creating new technical systems and technological processes, there is a need for statistical research and probabilistic assessment of phenomena occurring in the system and in the environment, by collecting and processing relevant statistical data, analogues and new samples of the technology being created.

The assessment of when it is worth setting the task of creating a fundamentally new technical object can be established by indicators that characterize activity in terms of development and changes in demand for a technical system.

The first peak in the number of inventions corresponds to the period of transition to mass application of the system, the second is caused by the desire to extend the life of the system.

The nature of the curve shown in fig. 5.4, c), shows that the first inventions that form the basis of the technical system are always of a high level.

Gradually, this level decreases, while there is a peak that corresponds to inventions that provide the system with the possibility of mass use.

Despite the fact that the first inventions are inventions of a high level, they do not give an economic effect, because the technical system is still being created and it has shortcomings and shortcomings.

The demand for a technical system does not always fall to zero even after the development of new, more efficient systems. The old machines will continue to be used, albeit on a smaller scale.

The demand curve for a technical system can also be presented in the form of the first derivative of the previous curve.

Analysis of demand curves for various objects and technical systems shows that the wavelength of these curves is getting shorter over time. Therefore, scientific and technical progress leads to the fact that the duration of use of products is shortened.

On the other hand, with the acceleration of the production of new products, the amplitude of demand for them increases. It follows from this that it is necessary to speed up the development of new products and systems.

The useful period of the existence of a technical system, that is, the duration of its use, depends on its value (technical level), wear and, in addition, the appearance of a new, more perfect system of the same purpose, that is, on the pace of technical progress.

Therefore, despite the natural desire of the consumer to use the usual technical system as long as possible, the need for a more efficient system turns out to be stronger.

Control questions and tasks for self-study

1. What is the improvement of car quality?
2. How has the development of technical objects been since the emergence of a new species that occurred as a result of a jump?
3. Until what time does the development of technical objects take place?
4. What leads to the emergence of a new type of technical objects implementing more advanced technology?
5. What is the ratio of the rates of development of science, technology and production?
6. What are the reasons for the change in demand for a technical object and how does it affect the development of technical objects?
7. When should the task of creating a fundamentally new technical

object be set?

8. What is the purpose of the progressive development of technology?

9. In what form of dependence can the development of science over time be represented mathematically?

10. What does the researcher A. Polovynkin recommend if, in the presence of the necessary scientific and technical potential, the transition to a new technical solution or principle of action provides additional efficiency that significantly exceeds additional intellectual and production costs?

11. According to what dependence is the increase in the constructive complexity of technical systems, when each newly created or improved technical system has a higher level of consumer properties R and technical complexity S compared to its counterpart?

12. Why is the necessary completeness of knowledge and understanding achieved only as a result of a series of iterations?

13. Why is there a need for statistical research and probabilistic assessment of phenomena occurring in the system when creating new technical systems and technological processes?

15. What depends on the useful life of a technical system, that is, the duration of its use?

LECTURE OUTLINE 6

PLAN

6. Information provision of scientific and technical creativity
6.1 Properties of information
6.2 Main sources of information
6.3 International classification of patents for inventions, utility models, industrial designs and commodity services
6.4 Patent documentation search
6.5 Processing and evaluation of information
Control questions and tasks for independent solution

6.1 Properties of information

Information is information about the environment, processes taking place in it, events and states perceived by people, controlled by machines and systems.

Information is knowledge that is the object of preservation, transformation and distribution in scientific and technical communication systems.

Creativity is reduced to changing and establishing new connections between existing knowledge. Therefore, the "achievements" of technical thought in publications, inventions of the past should in no case be considered only historical stages of the development of technology.

The ideas of past years, both implemented and not implemented in concrete technical practice, hold a colossal heuristic potential for the future.

The first rule of scientific honesty says: before starting any scientific work, it is necessary to familiarize yourself with all sources of scientific information devoted to this issue.

It is rather difficult to define the line between information and knowledge, since information in the strict sense is knowledge included directly in the communicative process.

In general, information can be defined as information that is the object of preservation, transformation and distribution in the system of scientific communications. It follows that not all information received by us can be classified as information.

The main features of scientific information are:

it is obtained in the process of recognizing patterns of objective sensitivity, proven by practice, and presented in the appropriate form;

it is documented or publicly announced information about domestic and foreign achievements of science, technology, research and development, production and economic activity.

From this we can draw conclusions: information does not have the properties of additivity and commutativeness and associativity; information that, at first glance, unrelated to the researched question, can give an impetus to the original solution of the problem. These properties of information create the main difficulties in its use.

Gathering the necessary information is one of the most time-consuming stages of creative activity.

6.2 Main sources of information

People realized the problems associated with the avalanche of information a long time ago.

On a clay tablet (Sumerian script, fourth millennium BC), archaeologists found the text: "Hard times have come: children have stopped obeying their parents and everyone is trying to write a book."

Currently, the field of knowledge has a great impact on the nature of information needs.

In different fields of knowledge, information processes occupy different specific weight in the general balance of a specialist's working time. According to the work [1-5], a research scientist spends about 50% of his time searching for information; according to the work [2] chemical researchers spend about 40% of their working time on information processes, radio engineering engineers - about 30%, light industry workers - about 12%.

The specific weight of information processes depends, in turn, on the rate of aging of information in this field of knowledge (approximately 4-5 years – in radio electronics, 6-8 years – in mechanical engineering, etc.) and on the degree of interaction of this field with other fields knowledge, in other words, from the need for related and cross-industry information.

The great expenditure of time on searching for information is explained, firstly, by the fact that scientific research cannot be carried out without it; secondly, information becomes outdated quickly: 10% per month – for magazines, 10% per year – for books and monographs.

The main sources of scientific and technical information are the following.

Reference journals. Currently, all large libraries have at their disposal a series of periodicals called abstracts and indexes.

Reference collections and indexes of articles exist in all fields of knowledge.

The abstract is a brief description of the author's articles with a message about who wrote them, when and where they were published.

Indexes of articles report the surname, first name of the author, title of the article, edition and date of publication.

Abstracts of monographs, articles, collections of educational literature, periodicals and other sources are given in reference journals.

Reference literature - encyclopedias, encyclopedic dictionaries.

Patent information is information about discoveries, inventions, industrial designs and trademarks from all fields of human activity in any country of the world.

Information about discoveries and inventions is usually concentrated in the patent funds of large libraries, enterprises and organizations, in abstract journals, as well as in bulletins about discoveries, inventions, industrial designs and trademarks.

The patent funds include patent classifiers, descriptions of patents and inventions, materials of the reference and search apparatus, normative and methodical literature.

Patent funds are divided into state (central), territorial and branch funds.

Special issues of technical publications are documents of an informational and advertising plan, analytical and statistical data on problems.

Printed documents are dissertations, reports on research works, separate works, reporting documents, methodical and instructional materials.

The reference and information fund is a collection of primary documents and a reference and information apparatus designed to meet information needs.

Information resources of general use are information resources of state bodies of scientific and technical information (library, firm, organization).

Bulletins of signal information include a bibliographic description of the literature published in certain fields of knowledge.

Express information contains extended abstracts of articles, descriptions of inventions and other publications.

Analytical reviews give an idea of the trends in the development of a specific field of science and technology.

Catalogs and card files of libraries and reference and information departments.

Internet system.

Usenet teleconferences are intended for receiving the latest news, exchanging ideas and opinions, and receiving the necessary consultations.

6.3 International classification of patents for inventions, utility models, industrial designs and commodity services

The International Patent Classification (IPC) covers all types of technology. It is a hierarchical classification, which is characterized by a functional and branch structure.

Structural elements of IPC are as follows: section, subdivision, class, subclass, group, subgroup.

According to the IPC, all inventions are divided into eight sections.

Sections have titles and indexes. Indices are denoted by Latin capital letters from A to H.

Titles of the sections: A - satisfaction of human vital needs; B – various technological processes; C – chemistry and metallurgy; D – textiles and paper; E - construction; F – applied mechanics, lighting and heating, engines and pumps, weapons and ammunition; G – technical physics; H - electricity.

Each section can contain up to 99 classes.

Individual class numbers may be omitted in order to add new classes as needed.

As you can see, the name and content of section "B" reflects the functional principle. Sections D, E, as well as some others are thematic.

Subsections have only headings.

The class name contains a header that reflects the content of the class and an index consisting of a section index and a two-digit Arabic number.

A class contains one or more subclasses.

The subclass index consists of the section index and the class index.

They are followed by a capital Latin letter. For example, the class D 03 has subclasses that have the following entry: D 003 C, D 003 D, D 03.

The title defines its content. The subclass is divided into main groups and subgroups.

The full index of the main group consists of the index of the subclass, followed by a one-, two- or three-digit number, a slash and two zeros. For example, subclass D 03 D covers the main groups: 1/00, 3/00, 5/00 – 51/00.

The full sub-group index consists of the sub-class index, a one-, two- or three-digit number of its main group and a slash followed by two, three or four digits. For example, group D 03 D 3/00 includes subgroups 3/02, 3/04, 3/06, 3/08.

There is a special IPC council at the World Intellectual Property Organization, which constantly improves the patent classification of the IPC and issues a new version of it every five years.

At the same time, the next edition of the MKI is indicated by an Arabic numeral and is placed before the index. A complete classification index consists of section, class, subclass, main group and subgroup indexes.

For example, index 6.H.01.B.8/05 means: the sixth edition of the IPC, section H - electricity, class 01 - elements, subclass B - capacitors, group 8 - electrolytic, subgroup 05 - tantalum.

6.4 Patent documentation search

Patent search is one of the types of information.

It is aimed at establishing the level of the technical solution, the limits of the rights of the owner of the security document, and the conditions for the realization of these rights.

There are three main types of search:

1) thematic (subject);
2) numerical;
3) nominal.

Thematic search is the most important and most widespread procedure. Keywords (descriptors), corresponding indexes of various classification systems, document titles or its elements that have a significant meaning (as a rule, these are terminological phrases, etc.) are used as a search sample.

Thematic search can be performed not only by the fund of inventions, but also by the funds of applications for inventions, as well as by the funds of utility models and industrial designs.

Thematic search involves the use of various information and search systems. Such systems increasingly rely on electronic computing technology.

Systematic indexes (which, in turn, are current, annual, final) are used for thematic search.

Narrow-profile information and search systems are also used.

Patent search begins with the establishment of a classification index.

Numerical search. As you can immediately guess from the name, we are talking about a search if the number of the security document (or application) is known.

Information about such a number can reach an interested person in different ways. To find the desired number, it is necessary to find the classification index given to the number using the numbering index. After that, you should look for the number in the fund. In the numbering indexes of applications, for each application number, as a rule, the number of the security document issued by the patent office is indicated.

Search by name. When conducting such a search, the starting point is the name (surname) of the owner of the patent, certificate, applicant, valid author, representative of the applicant (patent attorney). There is a search for establishing links between patent holders for the same object of industrial property in different countries or between the authors of the invention and the patent holders.

When performing a search, trade and economic directories, annual reports of companies, advertising booklets are used.

Search systems. There are the following search systems: documentary, factual, combined (hybrid).

The first of these contain information that reflects the content of the documents. Factographic systems concentrate formalized information. With the help of hybrid search systems, the search is conducted both by formalized elements (for example, by bibliographic data) and based on the substantive analysis of the document.

According to the method of their operation, search systems are divided into manual, mechanized and automated.

6.5 Processing and evaluation of information

To reduce the time of searching for the necessary information, it is worth introducing the concept of "rank of publications" and studying in detail publications with higher ranks.

The rank of the publication is determined by a preliminary quick review of the material or on the basis of publication in a refereed journal.

It is possible to distinguish 10 ranks of publications [2].

1. The publication reports on the discovery of new physical effects (a physical effect is understood as the relationship of physical quantities in nature).

The discovery of new physical effects, as a rule, gives rise to new opportunities and new scientific directions.

2. The publication examines the dependence of the known effect on various parameters. These are important physical studies revealing the properties of the open effect.

3. Mathematical models (means of quantitative description of physical phenomena) are proposed.

4. Formulations of new problems that can be solved on the basis of known effects are formulated.

5. Methods of solving new problems are proposed.

6. Other, more partial, options for solving scientific and technical problems are offered.

7. Specific numerical or functional dependencies found by the author are published.

8. Is informed about technological achievements, construction of devices or devices based on known physical phenomena.

9. Some changes in the formulation, solution, or practical implementation of previously known (and already solved) problems are reported.

10. Previously known results are described under new names, terms or designations.

To determine the rank of a publication, as a rule, it is enough to read only the introduction and conclusion.

If, after reading a post, you cannot determine its rank, there is a high probability that it is very low.

When receiving new information, you should strive for generalization, that is, try to understand it as an extension of previously known knowledge.

Control questions and tasks for self-study

1. Explain the concept of "scientific information".
2. What are the properties of information?
3. What are the stages of accumulation and study of scientific information?
4. Outline the main features of scientific information.
5. Describe the main sources of information.
6. How is information processed and evaluated?
7. Explain the concept of "publication rank".
8. Draw a diagram of the process of collecting and analyzing scientific information.
9. What is the information processing technique?
10. What information and search classification is used in libraries?
11. In what form is information presented in abstract journals?
13. List the structural elements of the International Patent Classification (IPC) for inventions.

LECTURE OUTLINE 7

PLAN

7. Methodology of scientific knowledge of the surrounding reality
7.1. Processes of knowledge of objective reality
7.2. Methodical principles in scientific and technical creativity
7.3. Methodology of science
Control questions and tasks for independent work

7.1 Processes of knowledge of objective reality

A person's understanding of ignorance in any field of existence causes an objective need to acquire and spread new knowledge.

Knowledge is a practice-tested result of knowledge of reality, its adequate reflection in a person's consciousness.

The process of movement of human thought from ignorance to knowledge is called knowledge. This is the interaction of the subject and the object, the result of which is a new knowledge of objective reality in the process of practical human activity (industrial, scientific, intellectual).

In the process of any creative activity, a person has to do certain types of mental work, use certain canons of logic, use methods and techniques of system analysis, evaluate and measure the obtained results, compare them with previously obtained results, compare them with known analogues and prototypes.

Scientific knowledge is research characterized by its goals and objectives, methods of obtaining and testing new knowledge.

Research paves the way for practice, provides theoretical foundations for solving practical problems.

Practice provides factual material to science, which needs to theoretically understand and justify it, which creates a reliable basis for understanding the essence of the processes and phenomena of objective reality.

Scientific knowledge is inextricably linked with practice by means of mastering the surrounding reality. In practice, scientific knowledge is used as an ideal way to ensure the production of material values.

Scientific knowledge is designed to determine the path to practice, to provide theoretical foundations for solving practical problems.

Therefore, theory must be ahead of practice due to the element of scientific prediction. For science, providing knowledge is the main and immediate goal of human activity.

Since science, as a process and result of human thinking, is generalized in categories, regularities, laws and other intellectual forms, the results of scientific creativity are reflected in generalizations of facts, abstractions, concepts, theories, ideas, etc.

Science is always based on reliable knowledge, accurate measurements, rigorous evaluations and correct evidence.

Relative knowledge is distinguished by the incomplete correspondence of the image and the object.

Absolute knowledge is a complete, exhaustive display of generalized ideas about an object, which ensures the absolute correspondence of the image and the object in a certain period of knowledge.

A priori knowledge is that which is not based on experience, but is transferred to it and indicates the way of obtaining scientific knowledge.

Cognition can be sensory and rational.

Sensory cognition is the result of a person's direct connection with the environment and is realized through the elements of sensory cognition: sensation, perception, representation and imagination.

Sensation is a reflection in the human brain of the properties of objects or phenomena of the objective world perceived by his senses.

Perception is a reflection in the human brain of the properties of objects or phenomena of the objective world, which are perceived by his senses in a certain period of time and form a defined sensory image of an object, phenomenon, or process.

An image is a secondary image of an object, a phenomenon, a process that does not act on a person's sensory organs at this moment in time, but must have acted earlier.

Imagination is the imaginary transformation of experience and knowledge, which leads to the formation of visual images that are not observed. This is the systematization of various ideas in the human brain, combining them into a coherent picture of images.

All known methods of learning and solving creative problems can be conditionally divided into two large groups based on the dominance of intuitive (heuristic) or logical (rational) procedures and their corresponding rules of activity.

Rational cognition is mediated and generalizing reflections in the human brain of essential properties, causal relationships, and regular connections between objects, phenomena, and processes. It promotes awareness of the essence of the process, determines the regularity of their development. The form of rational cognition is abstract thinking, various human reasoning, the structural elements of which are concepts, judgments, and conclusions.

The method of abstraction is widely used in scientific research. Abstraction is a way of thinking that involves the reflection of objects and phenomena of objective reality in human consciousness, imaginary separation from their secondary properties and relationships, and the selection of a common feature that characterizes a class of objects.

For example, when studying the operation of the mechanism, a calculation scheme is analyzed that reflects the basic, essential properties of the mechanism, or it is formalized in the form of formulas or special symbols.

The main types of abstraction are: isolating (which isolates the studied phenomenon from a certain integrity), generalizing and idealizing (replacing a real empirical phenomenon with an idealized scheme).

The concept of "abstract" is opposed to concrete.

Ascent from the abstract to the concrete - a method of object research, which consists in the transition from abstract and one-sided knowledge about it to a more concrete reproduction of the object in theoretical thinking - as a system of scientific definitions; the general law of the development of human knowledge, one of the basic principles of dialectical logic.

Logic is the science of methods of proof and refutation; a set of scientific theories, in each of which certain methods of proof and refutation are considered.

Aristotle is the founder of logic. Inductive and deductive logic are distinguished, and in the latter - classical, intuitive, constructive, modal.

All these theories are united by the desire to catalog such ways of judgments that lead from true reference judgments to true consequential judgments. Cataloging is performed, as a rule, within the framework of logical deductions.

A special role is played by the application of logic in computational mathematics, automata theory, computer science, [11].

The question of the truth or falsity of statements is considered and resolved on the basis of studying the method of constructing statements from so-called elementary statements using the logical operations of conjunction (AND), disjunction (OR), negation (NOT), implication (if.., then …).

Scientific concept – reflects scientific knowledge about a subject or phenomenon.

To define scientific concepts, scientific terms are used - a word or a group of words in which this scientific concept is strictly fixed.

The set of scientific terms used in certain branches of science and technology creates the terminology of the field, fixed in the relevant normative materials. For example, an electric drive is defined as an electromechanical device designed to provide motion to the working body of the machine and to control its technological process.

Another example of the reflection of scientific knowledge can be the widespread term "automaton". An automaton is an independently operating technical device that performs the processes of obtaining, transforming, transmitting, and using energy, material, and information according to a given program without the personal participation of a person.

Terminology is the language of science, which defines basic scientific terms, their meanings and connections between them. The incorrect use of scientific terms introduces confusion and misunderstanding in the interpretation of scientific concepts.

However, in scientific writings, it is sometimes necessary to introduce a new concept or clarify what was previously known, because knowledge develops and changes over time.

The meaning of concepts becomes obsolete. However, one should be quite careful with this logical operation, because it is easy to make mistakes here.

To define a concept means to explain it with the help of other, for example, more well-known concepts, and as a result to describe in this way a part of the reality for which it is intended to be described.

A typical example is the definition: a voltmeter is an electrical measuring device designed to measure voltage. Here, the scope of the concept "electrical measuring device" is the set A, the scope of the concept "voltmeter" is the set B, and B is a subset A ($B \subset A$).

7.2 Methodical principles in technical creativity

Scientific and technical creativity begins with an understanding of the inadequacy of some "part" (element, side, sphere) of the reality surrounding a person: the existing structure, technological process, the ratio of details in this or that technical complex, the operating conditions of the equipment, etc.

This is nothing more than inclusion in the context, the "push" of creativity (as a problem); this is the spark that ignites the bonfire of creative fire.

Discernment of insufficiency is the beginning of creativity. If you have determined what needs to be changed, what is important to improve, transform, you have solved half the problem.

Without such awareness, there is no need to search, that is, there is no creative thought. This is the basis of the approach to the new, the basis of the formation of the path of movement towards the new.

The problem is, firstly, the judgment of insufficient knowledge and disclosure, and secondly, the ways of finding a possible solution. It is possible, acceptable. This, in the essence of the matter, is "distraction" - it is often not yet completely clear.

When solving a problem (in each specific case), the reason for the emergence of a creative beginning, the basis for building (or finding ways to build) a new technical subject is revealed.

Actually, the justification of technical creativity acts as the main reason for the creation, evolution, and change of technical objects, processes, and phenomena.

No serious technical product can be created without justification. Through justification, the subjective side (subjective requirements and subjective resources) relies on the objective side: from the basis of the actor's inclusion in the context of activity.

Justifications allow us to understand the essence of combinations of components of technical activity (objective requirements and resources, subjective requirements and resources), and in the defined content also their formation. In such a union, the main content of the creative act is revealed.

From the variety of properties and aspects of reality, a person "chooses" those that ensure (justify) the achievement of the required result.

The relationship between the objective and the subjective (as a set of foundations) appears in the form of a method of activity.

A method is a set of techniques or operations of practical or theoretical mastering of reality, subordinated to the solution of a specific problem. It acts as a characteristic of techniques used to achieve a certain goal.

From this point of view, the method can be regarded as a peculiar form of means of activity, but a means of a special property: a "methodical" means, means-base, means-principle, method, rule, method, approach, system of provisions, categories, laws, etc.

In fact, the difference between method and theory is functional: being formed as a theoretical result of previous research, the method acts as a starting point and a condition for future research.

The method seems to consist of foundations of various kinds. But this is not a mechanical addition, but a kind of alloy.

The most significant principles in the analysis of groups of foundations from the standpoint of managing processes in technical creativity can be called the positions determined by the actor himself in relation to the conditions of activity under specific, objective circumstances.

In fact, we are talking about the types of human thinking: visual-active, conceptual-logical and sensory-figurative.

In this plan, it is possible to formulate the foundations that reflect one or another predominantly oriented approach of the acting person to the issues being resolved.

7.2.1 Visual thinking

Visual thinking is a direct form of connection with reality based on practice. Practice is the basis of technical activity, which determines it from the point of view of the concreteness of actions, their direct connection with creative tasks.

Practical foundations appear here, including empirical assessments of existing technical objects, their advantages and disadvantages, identified trends in the transformation of the existing fleet of machines, reconstruction of enterprises, housing systems, transport...

The focus here is on the development of practically transforming activities.

Practice, variously "pushing" things together, with work tools, instruments, observation devices, etc., allows you to reveal the causal relationship of phenomena, their properties, spatial and temporal relations, laws of movement of things, etc.

Practical (empirical) foundations of technical activity are manifested in the form of work experience, work skills, abilities, production (technological) traditions.

The ability to "think with your hands" is of particular importance here.

The practical basics of activity are mastered by the participants of the technical process during their qualification training as relevant specialists (training, work at certain factories, operation of certain technical objects, their repair).

Each of these participants has their own specific arsenal of practical skills and knowledge, determined by a number of factors, both objective and subjective.

Practical foundations in technical creativity determine the closest connections between an engineer's activity and a specific "active environment". Such inclusion of a person in specific circumstances ensures success in creative pursuits. This once again emphasizes the importance of including the actor in the context of the activity.

7.2.2 Conceptual-logical type of thinking

Conceptual-logical type of thinking is most closely related to the formation of scientific foundations of technical activity.

Turning to scientific foundations in technology is a historical necessity, since the use of only empirical foundations is not enough - they do not allow us to reveal the principles of the functioning of technology with the appropriate degree of depth.

It is necessary to go beyond the individual's experience into the world of the laws of nature: "without a scientific justification, the production of technology comes to a dead end, it is suppressed by the deepening of the contradiction between the social nature of technology and the isolated way of its construction."

The variety of empirical knowledge is developed in the system of a number of technical sciences; at the same time, the creation of a project language is of particular importance: projection drawing, sketch geometry, schemes, graphs, diagrams, regulatory bases - standardization, unification, typification, interchangeability, as determined principles of limiting diversity in technology.

One cannot underestimate the growing heuristic role of scientific justifications in technical activity, which reflect the essence of the processes taking place in technology.

Technical inventions, distinguished by many special qualities, originality, progressiveness, originate precisely from the idea of their preliminary scientific justification.

7.2.3 Sensory-figurative type of thinking

Sensory-figurative type of thinking is connected with figurative bases of activity.

Imagination and fantasy play a special role in this.

Sensory thinking is associated with such a mental reflection of reality, which gives not an indifferent copy of the objective world (which is characteristic of a more scientific approach), but a holistic image of a problematic situation, which includes a person's relationship to it.

"Visual thinking" plays a special role in the sensory and figurative aspects of activity in the field of technology creation, the product of which is the generation of new images and the creation of new visual forms that carry a certain semantic load and also make the meaning visible.

Also, the aesthetic relationship to reality plays a special role in the considered aspect.

The aesthetic reflects the position of the actor; it is saturated with the historically and biographically determined content of interests, aspirations, and feelings; acts as "the ability to see in a human way", the ability to endow the world with meanings, to see the object as a "sign", "mask", as the personification of something else.

The aesthetic attitude to the subject is also evidence of high professionalism and maturity of a person's creative outlook.

In the process of finding a new solution, the leading role belongs to the search for new foundations (new methods) or the change, transformation of existing ones.

A change in the foundations leads to the destruction of the formed system of relations between the components of activity and the opening of new opportunities in the development of creativity.

7.3 Methodology of science

The methodology of science is a system of methodological and methodical principles and methods, operations and forms of construction of scientific knowledge.

The philosophical level of methodology knowledge functions as a general system of dialectic principles.

Each branch of science has, in addition to the general ones, its own specific theoretical starting points that make up its theoretical foundation.

The issue of "methodology" is quite complex, since this very concept is interpreted in different ways.

Many foreign scientific schools do not distinguish between methodology and research methods.

In the domestic scientific tradition, methodology is considered as learning about methods of cognition or a system of scientific principles, on the basis of which research is based and the selection of a set of cognitive methods, methods, and techniques used in any science is carried out.

The technique is understood as a set of techniques, including techniques and various operations with actual material.

The methodology performs the following functions [10]:

determines methods of obtaining scientific knowledge that reflect the dynamics of processes and phenomena;

provides a special way by which the research goal can be achieved;

ensures comprehensive obtaining of information related to the process or phenomenon being studied;

helps to introduce new information;

provides clarification, enrichment, systematization of terms and concepts;

creates a system of scientific information based on objective phenomena and a logical-analytical tool of scientific knowledge.

These signs of the concept of "methodology", which determine its functions in science, make it possible to draw the following conclusion: methodology is a conceptual statement of the purpose and content of research methods that ensure obtaining the most objective, accurate, systematized information about processes and phenomena.

There are three types of methodology.

1. Philosophical, or fundamental - a system of dialectical methods

that are the most general and operate in the entire field of scientific knowledge, concretizing both through general scientific and through partial methodology.

2. General scientific methodology, which is used in the vast majority of sciences and is based on general scientific research principles: historical, logical, systemic, modeling, etc.

Modern researchers in scientific development prefer the system-active approach, that is, the study of the complex interaction of essential components according to the scheme: need → subject → object → processes → conditions → result.

This ensures integrity, complexity, structure, relationship with the external environment, purposefulness and self-organization of research, creates conditions for comprehensive study of any sphere of human activity.

3. Semi-scientific methodology – a set of specific methods of each particular science, which is the basis for solving a research problem.

Philosophical, or fundamental, methodology is the highest level of the methodology of science, which determines the general strategy of the principles of knowledge of the peculiarities of phenomena, processes, spheres of activity.

Philosophical methodology performs two functions. First, it reveals the essence of scientific activity and its relationship with other spheres of activity, that is, it considers science in relation to human practice, society, and culture. Secondly, the methodology solves the problem of improvement and optimization of scientific activity, is based on the worldview and general methodological guidelines and postulates developed by it.

All the achievements of the past were developed in the form of a dialectical method of knowing the real reality, which was based on the connection between theory and practice, the principles of knowing the real world, the interaction of external and internal, objective and subjective, etc.

The problems of scientific knowledge have become the subject of constant confrontation between different scientific views on the world, the essence of science and knowledge due to the antinomy in epistemology - the antinomy of rationalism-empiricism.

Based on the fact that every scientific research can take place on two levels - empirical, when the process of accumulating facts is carried out, and theoretical, on which the generalization of knowledge is carried out - in accordance with these levels, general methods of cognition are conditionally divided into three groups.

empirical research: observation, comparison, measurement, experiment;

theoretical research: idealization, formalization, axiomatic method, logical and historical methods, hypotheses and assumptions, systematic approach;

used at the empirical and theoretical levels: abstraction, analysis and synthesis, induction and deduction, modeling.

Control questions and tasks for self-study

1. What do you mean by the term "research methodology"?
2. What types of methodology do you know?
3. Define the terms "knowledge" and "scientific knowledge."
4. What is the process of scientific knowledge?
5. What are the structural elements of scientific knowledge?
6. Define the concepts of "absolute" and "a priori" knowledge.
7. Define the term "rational cognition."
8. Name the types of thinking used in technical creativity.
9. Describe the visual-acting type of thinking of knowing objective circumstances.
10. Describe the conceptual and logical type of thinking in the justification of activity.
11. Define the term "methodology of science".
12. What is fundamental methodology?
13. What general methods of cognition are used in scientific research?

LECTURE OUTLINE 8

PLAN

8. Methods of theoretical research
8.1. The creative process of theoretical research
8.2. Induction, deduction and idealization
8.3. Scientific ideas, hypotheses and assumptions
8.4. Theory and its structural elements
Control questions and tasks for independent work

8.1 The creative process of theoretical research

Theoretical research should be creative.

Creativity is the intentional creation of new values, new discoveries, inventions, the establishment of facts unknown to science, the creation of new, valuable information for humanity.

To disprove existing or create new scientific hypotheses, to deeply explain processes or phenomena that were previously unclear or poorly studied, to connect different phenomena together, i.e. to find the core of the researched process, to scientifically summarize a large amount of research data - all this is impossible without theoretical creative thinking.

The creative process requires conscious improvement of a known solution.

Improvement is the process of reconstructing the object of thinking in the optimal direction. When the processing reaches the limits defined by the previously set goal, the optimization process is stopped, the product of mental labor is created.

In the theoretical aspect, this is a research hypothesis, that is, a scientific prediction.

Under certain conditions, the improvement process leads to a unique, original theoretical solution.

Originality is manifested in a unique, unique point of view on a process or phenomenon.

The creative nature of thinking in the development of theoretical aspects of scientific research consists in creating representations of the imagination, that is, new combinations of known elements, and is based on the following techniques:

collecting and summarizing information;

constant comparison, comparison, critical reflection;

expressive formulation of one's own thoughts, their written presentation;

improvement and optimization of own provisions.

The creative process of theoretical research has several stages:

problem selection;

acquaintance with known solutions;

rejection of known ways of solving similar problems;

review of various decision options;

decision.

A creative solution often does not fit into a pre-planned plan.

Sometimes original solutions appear "suddenly", after seemingly long and futile attempts. The more known (typical, template) solutions, the more difficult it is to achieve an original solution.

Often, successful solutions arise from specialists in related fields, who are not weighed down by the burden of known solutions.

The creative process represents, strictly speaking, a rupture of usual ideas and a look at phenomena from a different angle. Own creative thoughts, original solutions arise more often, the more effort, work, and time is spent on constant consideration of the object of research, the more deeply the scientist is fascinated by research work.

The successful performance of theoretical research depends not only on the scientist's perspective, perseverance and purposefulness, but also on the extent to which he possesses the methods and methods of scientific research, and first of all, the dialectical method.

Methods of deduction and induction occupy an important place in the performance of theoretical research.

8.2 Induction, deduction and idealization

Induction and deduction are the most developed form of logical thinking, the result of which is an inference.

These methods are applied at the empirical and theoretical levels of research.

Induction is a type of generalization related to predicting the results of observations and experiments based on data from past experience.

This is the process of transition from knowledge of individual facts and events to more general knowledge, from facts to hypothesis, from experience to theory.

The process of induction usually begins with the accumulation of the results of observations and experiments, their comparison and analysis.

As the set of such data expands, a regular recurrence of some property of the object under study or some relationship between its parameters may appear.

There are several options for establishing a hereditary link by methods of scientific induction [8]:

a) method of single similarity: if two or more cases of the studied phenomenon have only one common circumstance, and all others are different (it is this similar circumstance that is the cause of the phenomenon under consideration);

b) the single difference method: if the case in which the phenomenon under investigation occurs and the case in which it does not occur are similar in everything and differ only in one circumstance, then this circumstance, necessary in one case and absent in the other, is the cause of the phenomenon, what is being investigated;

c) volumetric method of similarity and difference - a combination of the first two methods;

d) the method of accompanying changes: when the occurrence or change of one phenomenon causes some change in another phenomenon, then both of them are in a causal relationship with each other;

e) residual method: if a complex phenomenon is caused by a complex cause, which is a set of first circumstances and it is known that some of them are the cause of part of the phenomenon, then the remainder of this phenomenon is caused by the remaining circumstances.

A distinction is made between complete and incomplete induction.

With full induction, the inference exhaustively examines the phenomenon under study.

A more frequent technique in scientific research is incomplete induction, which includes the consideration of some features selectively, which allows to obtain in a short time, albeit an unreliable, but indicative, preliminary opinion about the subject.

Deduction is a thinking operation, which consists in the fact that new knowledge is deduced on the basis of knowledge of a more general nature, obtained earlier by summarizing observations, experiments, practical activities, that is, induction.

The principle of deduction: "from the general to the partial", that is, when individual provisions are deduced from general provisions and axioms.

When using the deductive method, we proceed from general rules or ideas, and then, through logical reasoning, derive from them separate consequences or predictions.

If, for example, we assume that eclipses of the moon are caused by the earth being in the path of the sun's rays and casting a shadow on the moon, then by deduction we can conclude that eclipses must recur again and again after a period of time sufficient for the sun and The moon, moving along its elliptical orbits, returned to the same position relative to the Earth.

This period of time should be the "smallest common multiple" of one lunar month and one solar year, that is, about 18 years [13].

The disadvantage of the deductive method of research is the limitations that arise from the general patterns on the basis of which a particular case is studied.

In order to comprehensively study the movement of a car, it is not enough to know only the laws of mechanics, it is necessary to apply other principles that arise from the analysis of the system "driver-car-environment".

So, the inductive method is a method of research in which general laws and principles are established based on individual facts and phenomena.

For example, Mendeleev, using certain facts about chemical elements, formulated the periodic law. A researcher, justifying the hypothesis of scientific research, establishes its compliance with the general laws of dialectics and natural science (deduction).

At the same time, the hypothesis is formulated on the basis of isolated factors (induction).

For all their oppositeness, induction and deduction are closely related, showing different sides of a single dialectical method of knowledge.

At the same time, idealization is the presentation of real objects or phenomena with simplified schemes for the purpose of more effective use of methods and means of their research.

The process of idealization is reduced to the numerical construction of objects or concepts that do not exist in reality or are practically not realized, but their similarity exists in the real world.

For example, in physics, the terms "absolute solid body" and "absolute black body" are used. In geometry, the concept of "point" is used, which refers to a spatial object that has no dimension.

It is obvious that such a representation of a point is the "purest" idealization, since in the real world there are no spatial objects that are not measurable.

Therefore, the goal of idealization is to deprive real objects of some of their properties and mentally endow these objects with some unreal and hypothetical properties.

At the same time, the goal is achieved thanks to:

multi-level abstraction;

the transition of thinking to the final case in the development of certain properties;

simple abstraction.

However, any idealization is legitimate only within certain limits.

Methods of analysis and synthesis play a special role in theoretical research.

Analysis is a method of scientific research in which the phenomenon is broken down into its component parts.

Synthesis is the opposite of analysis, which consists in the study of the phenomenon as a whole, based on the combination of interrelated elements into a single whole.

Logical and historical methods are used in theoretical research.

The logical method includes hypothetical and axiomatic.

The axiomatic method is based on obvious propositions (axioms) accepted without proof.

According to this method, the theory is developed on the basis of the deductive principle. It became more widespread in theoretical sciences (mathematics, mathematical logic).

The historical method allows you to investigate the emergence, formation and development of processes and events in chronological order in order to reveal internal and external connections, regularities and contradictions.

In applied sciences, the historical method is used in the study of the main stages of development and formation of certain branches of science and technology.

Observations are primary in learning the physical essence of processes.

Any process depends on many factors acting on it. Each observation or measurement can capture only a few factors. In order to fully understand the process, it is necessary to have a large number of observations and measurements. It is difficult to single out the main ones and then deeply investigate processes or phenomena with the help of a large amount of unsystematized information. Therefore, they seek to "condense" such information into some abstract concept - "model".

8.3 Scientific ideas, hypotheses and assumptions

The choice of a research problem is based on the researcher's idea.

An idea is a product of human thinking, a form of reflection in thoughts of actual processes and phenomena of objective reality.

A scientific idea summarizes the experience of the previous development of knowledge and practice and serves as the principles of unifying new, previously unknown phenomena and regularities.

A scientific idea is a form of reflection in thinking of a new understanding of objective reality. Therefore, a scientific idea is a kind of leap of thought beyond what was previously known.

Most scientific ideas are born from experiment or are related to experiment to one degree or another.

Other areas of scientific thinking are purely speculative.

Depending on the complete coverage of new knowledge and generalizations, a scientific idea can take the form and name of rules, principles, laws, concepts, paradigms.

The idea differs from other forms of thinking and scientific knowledge in that it reflects not only the object of study, but also the awareness of the goal, the prediction of knowledge and the practical transformation of reality.

New ideas can arise under the influence of paradoxical situations, when an unexpected result is revealed that strongly differs from the generally known positions of science - paradigms.

One of the luminaries of science formulated its concept as follows: "Paradigm is a stable system of interdependent scientific theories, concepts, principles and concepts prevailing in a certain period of time."

At the same time, the acquisition of new knowledge is carried out according to the following scheme: paradigm – paradox – new paradigm.

It can be argued that the development of science is a change in distinctive paradigms, methods, stereotypes of thinking.

The transition from one paradigm to another does not lend itself to a logical description, because each of them rejects the original one and brings a fundamentally new research result that cannot be logically deduced from the existing theory.

Intuitive mechanisms of scientific research, which are not based on formal logic, play a special role here.

A materialized expression of a scientific idea is a hypothesis.

A hypothesis is a scientifically based assumption about a directly observable fact or about a regular order that explains a known set of processes or phenomena.

Unlike a theory that reflects reliable scientific knowledge, a hypothesis is a form of possible scientific knowledge.

There are two types of hypotheses:

a theoretical hypothesis based on scientific regularities, methodological provisions, logical judgments, reasoned forecasting, fundamental knowledge;

the empirical hypothesis is based on the results of previous practical experience.

Thus, hypotheses are such assumptions or guesses that are resorted to when building a theory or when setting up an experiment aimed at directly testing a theory, if this is possible.

The hypothesis is the guiding idea of the research. It determines the direction and scope of theoretical developments.

After testing, the proposed hypothesis may turn out to be correct or incorrect.

One of the many sources of generating scientific hypotheses is the use of analogies.

Condition by analogy is a process when the knowledge obtained from the examination of some known object is transferred to a less studied object similar to it in some essential properties and signs.

Hypotheses, like ideas, have a probable character and go through three stages in their development:

accumulation of factual material and making assumptions based on it;

forming and substantiating the hypothesis;

verification of the obtained results in practice and based on the refinement of the hypothesis.

On the basis of hypotheses, the search for new scientific results is carried out - this is the essence and purpose of the hypothesis as a form of development of science.

The hypothesis is put forward in the hope that it, if not in full, will at least partially turn into reliable knowledge.

So, for example, hypotheses about the possibility of converting thermal and electromagnetic energy into mechanical energy, based on the law of energy conservation and conversion, became reliable knowledge after steam engines and electric motors were invented.

If the obtained practical result corresponds to the assumptions, then the hypothesis turns into a scientific theory, that is, it becomes reliable knowledge.

In practice, several hypotheses can be formed from the same unknown process or phenomenon, because any phenomenon is multifaceted and interdependent with others.

The presence of various hypotheses provides the necessary multifaceted analysis, without which strict scientific generalization is impossible.

The procedures by which the truth of any statement is established is called proof.

Evidence of hypotheses in object research can be known experimental data, formed theories.

Evidence uses two methods of establishing the truth: direct and indirect.

With the direct method, the truth is established in the process of practical actions - it can be observation, demonstration, measurements, calculation, etc.

In the indirect method, proof is a logical procedure for establishing the truth of any claim with the help of other statements, the truth of which has already been proven.

The structure of evidence can include the following elements: thesis (propositions, observations, opinions), argument and demonstration (illustrations of layouts, tables, schemes).

Theoretical and inventive activity and especially scientific research are based on the use of general laws of logic, laws and forms of thinking.

8.4 Theory and its structural elements

One of the results of scientific activity is the formulation of a theory.

Any scientific theory is related to general and partial research methods.

Theory is the highest form of generalization and systematization of knowledge, which gives a holistic idea of the regularities and main connections of reality.

The theory is built on the results obtained at the empirical level of research. It describes and explains the set of phenomena of some part of reality and reduces the laws discovered in this field to a single generalizing beginning.

In the theory, these results are ordered, fit into a coherent system united by a general idea, refined on the basis of the abstractions, idealizations and principles introduced into the theory.

The theory acts as a form of synthetic knowledge, within which individual concepts, hypotheses and laws lose their past autonomy and turn into elements of a coherent system of scientific knowledge.

A scientific theory based on knowledge of the objective laws of nature allows predicting phenomena that may occur in the future as a result of the actions of these laws (for example, Mendeleev's periodic law predicted elements that did not exist at that time).

The following requirements are put forward to the new theory [1-8, 10-13]:

the adequacy of the scientific theory to the described object, which allows, within certain limits, to replace experimental studies with theoretical ones;

completeness of the description of a specific field of activity;

the need to explain the relationships between various components within the theory itself.

The presence of connections between different provisions will ensure the transition from one statement to another;

lack of internal consistency of the theory and its correspondence to the researched data.

The theory should be heuristic, constructive and simple.

The heuristics of a theory reflect its ability to predict and explain.

The mathematical apparatus of the theory should not only provide accurate quantitative predictions, but also help discover new phenomena.

The constructiveness of the theory lies in the possibilities of a simple, carried out according to some rules, verification of its main provisions, principles and laws.

The simplicity of the theory is achieved by introducing generalizing laws, abbreviations and presenting information in a concise form using symbols [6].

A postulate is a statement that is accepted within the limits of a specific scientific theory as truth, without proof, and acts as an axiom.

The principle is the basis of great theoretical generalizations.

The principle is the main starting point of any scientific theory, teaching, science or worldview, it acts as the first and most abstract definition of an idea, as the initial form of systematic knowledge.

Formalization is a method of studying various objects by displaying their structure in a known form using an artificial language, for example, the language of mathematics.

The use of mathematical models is one of the main methods of modern scientific research.

With the help of analytical methods, the mathematical dependence between the parameters of the physical model is determined.

A mathematical model can be expressed using a functional relationship in the form of a system of algebraic, differential or integral equations.

Using analytical methods, a mathematical model is determined.

Such models have a large amount of information.

The advantages of formalization are:

providing a generalized approach to solving the problem; □ the use of symbols creates brevity and clarity of fixing values;

unambiguity of symbols (there is no ambiguity in ordinary language);

makes it possible to form separate models of objects and change the understanding of the real processes of studying these models.

However, the mathematical formalization has significant drawbacks.

In order to find a specific solution unique to this process in the entire class, it is necessary to set the conditions of unambiguity.

Determining the boundary conditions requires a reliable model experiment and a detailed analysis of experimental data.

Incorrect definition of the boundary conditions leads to the fact that the theoretical analysis is conducted not of the process that was planned, but of the already changed one.

In many cases, it is not always possible, or it is completely impossible, or it is very difficult to have a final analytical expression, taking into account the conditions of unambiguity, which most accurately reflect the real physical essence of the investigated process.

Often, when investigating a complex physical process with well-founded boundary conditions, differential equations are simplified due to the impossibility or excessive cumbersomeness of their solution, which changes its physical essence. Thus, very often it is very difficult to implement analytical approaches.

A concept is the result of a reflection in a person's mind of the general properties (or signs) of a group of objects or phenomena that are essential and necessary for distinguishing the group in question.

For example, the concept of "electric motor" was obtained by generalizing the essential features of numerous electric motors (in particular, the ability to convert electromagnetic energy into mechanical energy).

Each concept has meaning and scope.

The content of a concept is a set of features that distinguish this concept from another.

The scope of the concept is a set of objects, phenomena reflected in the concept itself.

For example, in the Ukrainian language, the concept of "person" is defined by the following features: a living being that has thinking, language, is able to create and use tools, unlike, for example, in German, where the concept of "person" has features: logical thinking, language , the ability to distinguish between good and evil, to make moral decisions and to be a higher living being.

The concept is a reflection of the most important and characteristic features of the subject, phenomenon or process. They can be general, partial, composite, abstract, concrete, absolute and relative.

In the process of development of scientific knowledge, the content of concepts can be clarified, new features can be added to it.

The most generalized and fundamental concepts are called "categories".

These are forms of logical thinking, in which the most important internal aspects and relationships of the studied subject are revealed.

In any generalization, the signs are chosen appropriately.

The goal changes over time, so each concept has a historical meaning. For example, the meaning of the concept "atom" (from the ancient Greek atomos - indivisible), introduced by Democritus, is quite significantly different from the modern meaning of this concept.

Axioms are propositions that are accepted without proof due to their obviousness.

Control questions and tasks for self-study

1. What is meant by the theoretical task of the research?
2. Methods of theoretical research and their brief description.
3. Define induction and deduction.
4. What are the methods of scientific induction?
5. Define idealization.
6. How do you understand the research hypothesis?
7. Define a scientific idea, theory, and law
8. State the structure of theory formation.
9. What is the structure of theory formation?
10. Define the features of a new theory.
11. Define the method of formalization.

LECTURE OUTLINE 9

PLAN

9. Method of empirical research
9.1. Observation and comparison
9.2. Measurement and experiment
9.3. Abstraction and generalization
Control questions and tasks for independent work

A method is a way of achieving a certain goal, a theoretical or practical solution to a particular problem.

A method is a set of techniques or operations of theoretical, practical, experimental study and knowledge of reality aimed at solving a specific problem.

The concept of "method" is very close to the concept of "theory".

The actual difference between them is only functional: the method reflects the theoretical result of previously conducted research and acts as a starting point and condition for conducting future research.

Methods of empirical research in theoretical sciences are: observation, comparison, measurement and experiment, statistics.

The data obtained by these methods are the basis for further theoretical understanding of cognitive processes and create a holistic unity of scientific knowledge.

9.1 Observation and comparison

Observation is a method of cognition in which an object is systematically studied without interfering with it.

In order to improve the effectiveness of surveillance, the following requirements must be met:

be conducted for a specific, clearly defined task in advance;

to be carried out according to a plan (planned) drawn up in accordance with the task;

only specific aspects of the phenomenon that are of interest for research should be observed;

the observer is actively looking for objects, features of the phenomenon;

be carried out continuously or according to some system.

Observation as a method of cognition makes it possible to obtain the first information in the form of a set of empirical requirements.

The empirical aggregate creates some schematization of the objects of reality - the original objects of scientific research.

Comparison is the process of establishing similar or distinctive features of objects and phenomena, as well as the presence of a common characteristic of two or more objects.

Comparison is a thinking operation, with the help of which the content of reality is classified, ordered and evaluated.

In the process of comparison, objects of creative activity are compared in pairs in order to identify their similar and distinctive features, correlations of their properties and technical characteristics.

When using the comparison method, the following requirements are met:

the comparison makes sense only in relation to a set of homogeneous objects forming a defined class or group;

the comparison should be made according to the most important essential features and parameters (within the plan of a specific task).

Comparability of subjects in a given class is carried out on the basis of features essential for this consideration. At the same time, objects compared by one feature may be incomparable with each other by another feature.

In the practice of creative and inventive activity, a comparison of new developments with analogs and prototypes known in the world practice is carried out.

An analogue is something that is similar, corresponding to another object, phenomenon, concept, device or method.

A prototype is the only one out of many, but the closest analogue, the one that has the largest number of features in common with the object in question.

Using comparison, information about the object is obtained in two ways:

direct result of the first comparison;

the result of primary data processing.

9.2 Measurement and experiment

Measurement is the determination of the numerical value of some value using a unit of measurement. This is an operation that determines the ratio of one measured value to another homogeneous reference value, usually taken as a unit.

The number expressing such a relationship is called the numerical value of the measured value.

In essence, any measurement of two or more quantities is reduced to their comparison by a selected feature (mass, length, power, speed, etc.).

Exact sciences are characterized by an organic connection of observations and experiments with the presence of numerical values of the characteristics of the studied objects.

The outstanding scientist-chemist Dmytro Ivanovich Mendeleev said on this occasion: "Science begins from the time one begins to measure."

Any measurement assumes the presence of the following basic elements:

of the object of measurement, the property or state of which is characterized by the measured quantity;

Unit;

method of measurement;

technical means of measurement graduated in selected units;

an observer or recording device perceives the result.

A distinction is made between direct and indirect measurement.

With direct measurement, the result is obtained directly during the measurement operation.

Mastered measurements are based on the use of known dependencies between the sought value of a quantity and the values of directly measured quantities. This is, for example, determining the forces acting on the structure by the magnitude of their elastic deformations, since, according to Hooke's law, this deformation (bending, compression) is proportional to the applied force; determination of clearance values in parts that are connected by the amount of increased vibrations, the change of which is proportional to the change of the clearance.

Measurement is a more powerful and universal cognitive method compared to observation.

The value of this procedure lies in the fact that it provides accurate quantitative information about the object of research.

An experiment is an approbation of knowledge of researched processes and phenomena under controlled natural or artificially created conditions.

An experiment is the most general empirical method of cognition, in which not only observations are made.

This is a method of studying an object, when the researcher actively and purposefully affects the object by creating the given conditions necessary to reveal the necessary properties.

An experiment is an important element of scientific practice, it is considered the basis of theoretical knowledge, a criterion of its validity.

The experiment is carried out:

if necessary, look for previously unknown properties in the object;

when checking the correctness of the theoretical structure;

when demonstrating the phenomenon.

The advantages of experimental study of the object in comparison with observations are as follows:

in the course of the experiment, it is possible to determine the phenomena, getting rid of side factors that overshadow the main process;

in experimental conditions, it is possible to study almost all properties of the object;

repetition of the experiment as many times as necessary.

In scientific research, experiment and theory are the most interdependent. Any disregard for the experiment leads to errors.

Expansion of experimental research is one of the main ways of development of modern science.

The methodology of the experiment is determined by its general structure, setting and sequence of carrying out the specified actions:

development of the plan - program of the experiment;

selection of means for conducting the experiment;

conducting an experiment;

processing and analysis of experimental data;

conclusions

Laboratory and production experimental studies are divided.

9.3 Abstraction and generalization

The abstraction method is used at the empirical and theoretical level of research (see Fig. 7.4).

Abstraction is a method of scientific research, based on the fact that when studying or analyzing an object, the researcher mentally singles out the most significant properties and features of this object that interest him, at the same time distancing himself from a number of its less significant in the given situation signs and connections. He assumes that the phenomena and their properties that occur in the object are supposedly independent of each other.

This approach allows to simplify the picture of the investigated phenomena, to separate the most significant and general signs from other, less significant and particles.

The abstraction process has two stages.

The first: highlighting the most important in the phenomena and establishing the fact of independence or minor dependence of the studied phenomena on some facts that can be ignored. For example, if object A does not directly depend on factor B, then it can be left aside as insignificant.

The second stage: implementation of the possibilities of abstraction.

The essence of abstraction is that one object is replaced by another, simpler one, which acts as a "model" of the first one.

Abstraction can be applied to real and abstract objects, that is, those that have undergone abstraction earlier.

Multi-level abstraction leads to abstractions of an ever-increasing degree of justification.

Abstraction makes it possible to replace the complex in cognition with a simple one, but such a simple one that reflects the main thing in this complex.

"Abstract" means nothing more than imaginary separation from a number of properties of objects and relationships between them in order to highlight their essential features.

Abstractions, depending on the purposes of their use, can be of the following types: isolating, identifying, generalizing and idealizing, constructivizing, actual infinity, potential realization [1-5, 10-13].

Isolating abstraction is used for the purpose of isolating the investigated phenomenon from some integrity of the object in order to identify and fix its qualitative and quantitative regularities. This is the selection of properties and relations inextricably linked to the subject and their designation by some "names", which gives abstractions the status of independent subjects (for example, "reliability", "technological").

The difference between these two abstractions is that in the first case a complex of object properties is isolated, while in the other case its only property is isolated.

Identification is the formation of a concept through the unification of objects connected by equality-type relations into a special class, while leaving aside some individual qualities of objects.

Idealization is the presentation of real objects or phenomena with simplified schemes for the purpose of more effective use of methods and means of their research. The process of idealization is reduced to the imaginary construction of concepts about a non-existent or practically unrealized object, but which have prototypes in the real world. For example, in geometry, the concept of "point" is used, which means a spatial object that has no dimensions.

Obviously, such a representation of a point is the "purest" idealization, since in the real world there are no spatial objects that cannot be measured. After all, even the diameter of the nucleus of an atom has a dimension, and it, by the way, is numerically equal to one angstrom, that is, 10^{-10} m.

Concepts of "line", "inertia", "absolute black body" and others have a similar character of idealization.

A sign of scientific idealization, which distinguishes it from fruitless fantasy, is that the objects created by idealization under certain conditions are interpreted in terms of non-idealized (real) objects.

It is practice, including the practice of scientific observation and experimentation, that confirms the legality of the processes generated by the idealized object and serves as a criterion for the fruitfulness of idealization in the process of cognition.

A modern researcher often first sets the task of simplifying the phenomenon under study and building its abstract idealized model.

Idealization acts here as a starting point in theory construction. In particular, the creation of a linear theory of automatic control is based, first of all, on such an idealized concept as "linear determining link". The criterion for the fruitfulness of this idealization is the satisfactory coincidence of theoretical and empirical research results in many cases [9].

Constructivization is a deviation from unusualness between real objects.

Actual infinity is a deviation from the incompleteness (and impossibility of completion) of the process of creating an infinite set, from the impossibility of specifying it with a specific list of all elements.

Such a set is considered obvious.

Potential realization is a deviation from the real between human possibilities caused by the limitations of life in time and space.

Infinity is seen as potentially realizable. From the very beginning, the modern researcher sets the task of simplifying the phenomenon under study and building its abstract, idealized model.

At the same time, idealization serves as a starting point in building a theory.

Experiment and practical experience, the degree of similarity of theoretical and empirical results serve as a criterion for the legality of any idealization, accepted at the same time as assumptions and simplifications.

But the expressed idea is still subject to verification by life experience before its full recognition.

A generalizing abstraction is used to obtain a general picture of the phenomenon under study, to create a concept through the unification of objects related by the relationship of the sameness type into a special class.

On the basis of the sameness of some set of objects, similar in their characteristics, the construction of an abstract object is carried out. For example, such an abstract concept as "amplifier" summarizes into one functional group many amplifying devices, devices and mechanisms, different in their physical nature, energy carriers (magnetic, hydraulic, pneumatic), branches of technology and other features.

At the same time, all of them are characterized by the same properties: amplification factor, passband, inertia, delay, etc., which are of primary importance and most significant in the synthesis and construction of new technical objects.

Generalization is a logical process of transition from individual to general, or from less to more general knowledge.

It is a product of mental activity, a form of reflection of general features and qualities of objective phenomena.

Generalization is a transition to a higher degree of abstraction by identifying common features (properties, relationships, development trends, etc.) of subjects in the field under consideration. This is one of the most important means of scientific knowledge, which allows you to extract general principles and regularities from many chaotic phenomena, identify and unify many objects and events in a single formula.

As a result of generalizations, new concepts, laws, and theories appear in some cases, and in others, their new versions, variants, and modifications are given.

According to the semantic and epistemological (cognitive) content, generalizations are divided into two types.

1. Generalizations that give rise to new concepts, laws, principles and theories that are not determined by the original semantic field. All so-called "theoretical generalizations" or "generalizations through abstraction", which in cognition correspond to the transition to a higher level of abstraction, belong to this type of generalizations. In particular, these are generalizations made on the basis of an idealized imaginary experiment that gives rise to hypothetical principles similar to the principles of inertia and relativity.

This is also generalization through identification by properties, which allows us to reveal the general essence of differently perceived phenomena. For example, the fact that magnetism, electricity and light are just different manifestations of the electromagnetic field.

2. Generalizations that do not give rise to new concepts, but only give new versions of old ones. It can be extrapolation - spreading the principles known in one area of knowledge to another.

Such generalizations include, for example, incomplete induction - the spread to all substances of a known property of a substance - to be in several aggregate states.

Control questions and tasks for self-study

1. Define the empirical task and research methods.
2. Describe the methods of observation and comparison.
3. What requirements can be used to increase the effectiveness of observations?
4. Describe the experimental method of cognition.
5. In what cases is the experiment conducted?
6. What are the advantages of experimental study in comparison with observations?
7. What is the sequence of the experiment?
8. Describe the methods of abstraction and generalization.
9. Describe the concepts of potential implementation and generalization.

LECTURE OUTLINE 10

PLAN

10. Heuristic methods of finding ideas and solving scientific and technical problems
10.1. Logic and intuition.
10.2 Logical operations and laws of mathematical logic
Control questions and tasks for independent work

10.1 Logic and intuition

Ever since man began to consciously improve existing and invent new technical objects unknown to him, he simultaneously began to create and improve methods of finding the most rational and effective technical, technological and business solutions.

Increasing the productivity of thinking in the field of technical creativity becomes one of the main problems of modern science, the main direction and source of increasing the effectiveness and quality of entrepreneurial and inventive activity.

All existing methods, methods and techniques of human creative activity are conventionally divided into three types by the nature of mental operations: intuitive, heuristic, algorithmic (computer).

Intuition is the ability to directly understand the truth. The results of intuitive cognition are logically proved and verified by practice over time.

Intuition is a direct understanding of the truth (without any logical justification in conditions of incomplete initial information about the object), based on a person's insight, intellectual sense and education.

It is due to this property of intelligence that some people manage to find the most rational and best of the best solutions in the process of developing a new technical object or business project due to their own intuition.

But, as a rule, the intuitive method brings good results only to a small number of lucky people: experienced professionals or especially gifted people in the form of knowledge hidden from the subject himself.

From the point of view of psychology, heuristics is a science that studies creative thinking.

Philosophy considers those judgments that contribute to new discoveries to be heuristic. Heuristic operations are a type of thinking that creates a new system of actions or discovers previously unknown regular phenomena of objects of science.

Heuristic methods are understood as a method of solving a problem that either limits the choice of solution options, or narrows them down to a minimum number, which leads to the solution of a complex, non-standard problem.

Heuristic methods, as ready-made schemes (gained experience with a goal), are the object of heuristic logic and can be presented in the form of a separate logical scheme of mathematical logic, when any task can be solved by known rules, by analogy.

The main element of heuristic scientific knowledge is the logic of scientific research, which is understood as a defined path in scientific research.

Scientific research requires a logical sequence of defined stages, the basis of which is rational thinking, as a reflection of the laws of real reality, which meets the following requirements: concreteness, consistency, reasonableness.

Logic is the science of laws, methods of correct construction of thought aimed at knowledge of objective reality.

The main tasks of logic are:

achieving the truth of knowledge;

construction of the structure of the imaginary process;

using the right methods of cognition.

Logic is a collection of a number of sciences about the laws and forms of thinking, which differ only in which laws of thinking make up their subject (mathematical, combinatorial, dialectical logic, etc.).

The forms of thinking and laws of logic include such categories as "concept", "judgment", "condition", "reasoning", "postulate", "axiom", "principle", "category".

At the same time, the following are used: mathematical, combinatorial, dialectical logic.

The correct application of the laws of mathematical logic is a necessary, but not always sufficient, condition for reaching the truth.

Dialectical logic contains general methods of movement of thinking to new results, logical principles of transition from known to new knowledge.

The study and use of certain methods, techniques and concepts of this huge science, which is also quite important for a creative personality, is provided for by many school, and then university educational disciplines.

Specialists face the task of building and analyzing real objects. But instead of solving it directly, they first abstract from all the details of reality that are not essential for solving the problem. Then they choose a model that reflects the essential details of reality, use methods of transformation and analysis of models developed by theorists. After that, the original problem is solved with the help of interpretation and application of these theoretical results in a real object.

For specialists, the problem of checking and ensuring the adequacy of the used models is decisive.

Also important is the problem of choosing among many formal such models, within which the original problem has a solution.

Most often, the framework of the model imposes significant restrictions on the applicability of the results of this approach in a real object.

So, a reasonable division of labor has developed in modern science: theorists usually do not deal with the issues of using their theoretical constructions, and engineers usually do not build new formal models.

Logic studies the forms of thinking and ways of their expression in language.

Formal mathematical logic solves the problems of checking the correctness of reasoning in natural language (the real world), building its models and the rules of their transformation.

For this, logic introduces its own language - a system of formal notations (formulae) and the rules of their transformation.

Therefore, logic can be considered as a set of rules for manipulating formulas that describe the statements of natural language.

10.2 Logical operations and laws of mathematical logic

There is a whole science - the algebra of logic - the subject of which is logical operations on judgments.

Let's consider the five most common logical operations on judgments [1-5].

1. Denial (logical operation "no").

With this operation, a new judgment is obtained, which is true if the original judgment is false, and vice versa.

For example, there are two judgments: A - "The electric motor is working" and B - "The wires that connect it to the electrical network are not connected." Then statement B is true, if statement A is false.

This operation of mathematical logic is written as A =$\bar{B}$, where a dash above the symbol "B" means negation, and the entry reads as follows: "A is not equal to B."

2. A conjunction (logical operation "and") is formed from two or more judgments and is true when each of these initial judgments is true, and false when at least one of the initial judgments is false.

If, for example, an electric motor is said to be running because A is "the wires are connected to the grid" and B is "the grid is live," then the statement is true. If one of the two judgments A or B is incorrect, that is, either the wires are not connected or there is no voltage in the electrical network for some reason, then the judgment about the working electric motor will be wrong.

This operation is recorded as follows: (A $\wedge$ B), and is read as "A and B».

3. A disjunction (logical operation "or") is also formed from two or more simple judgments. It is true when at least one of the original judgments is true, and it is false when all the original judgments are false.

For example, the judgment that an electric motor will work if it is A - "it is connected to a live electrical network, or B - when it is connected to a charged battery in an emergency mode, will be true if at least one of from the two named sources, and is incorrect if both sources are de-energized at the same time.

The disjunction operation is written as follows: (A $\vee$ B), and reads "A or B" or "both together".

4. Implication is a logical operation that connects two statements into a complex statement by means of a logical connection, which corresponds to the conjunction "if ... then ..." in everyday language.

It is symbolically represented by a sign «$\rightarrow$», that stands between judgments A and B (A $\rightarrow$ B), and reads: "if A..., then B...".

Let us give an example of an implication. If the wires are connected to the electrical network (A), which is under voltage (C), then the electric motor will work (B).

An implication means that B is false when C is true and A is false.

Indeed, if the wires are not connected to the network (false judgment), then the electric motor will not work either (false judgment).

An implication is always a conditional judgment, but it does not always imply a causal relationship between A and B.

5. The equivalence of judgments A and B is judgment C, which is true when A and B are both true or false at the same time.

The equivalence operation is denoted by the sign "tilde" (~), i.e A ~ B is read as follows: "A... then and only if B...».

Equivalence, like implication, is a conditional judgment.

An example of equivalence: a judgment is expressed that the electric motor will work (A) if and only if the wires are connected to the electrical network (B) and the electrical network is energized (C).

On the other hand, the equivalence of A and B is false if and only if one of the statements included in this complex statement is false and the other is true.

Indeed, both in the absence of voltage in the supply network (C=0), but with connected wires (B = 1) and with the network under voltage (C=1), but with unconnected wires (B = 0) voltage will not be applied to the electric motor and, accordingly, it will not work.

The logical operations considered above can be clarified using the table for better clarity of their interpretation. 10.1.

Table 10.1 – Logical truth operations

A	B	$\bar{A}$	$A \wedge B$	$A \vee B$	$A \rightarrow B$	$A \sim B$
0	0	1	0	0	1	1
0	1	1	0	1	1	0
1	0	0	0	1	0	0
1	1	0	1	1	1	1

When describing the results of research and analyzing creative developments, both types of conditional judgments are widely used - implication and equivalence.

At the same time, in order to avoid misunderstandings, it is necessary to discuss which judgment is meant.

Suppose the following conditional judgment is expressed: "If an electric current flows through the conductor (judgment A), then the conductor heats up (judgment B)." According to a well-known law of physics, this statement is true.

But if this judgment is converted and said: "If the conductor is heated, then an electric current flows through it", then it may turn out to be wrong, because the conductor can be heated either by heat transfer from the surrounding air or even due to solar energy.

In other words, the implication does not have the property of symmetry, that is, $A \rightarrow B \neq B \rightarrow A$.

When solving various problems that arise in the process of conducting scientific research, the use of the apparatus of logic algebra turns out to be quite fruitful.

Example. A technical device consists of a group of elements. As a result of the experiment, it was found that 70% of the elements (set A) fail due to an increase in temperature, and 60% (set B) - due to increased vibrations.

What fraction of elements fail as a result of increased temperature and increased vibration?

It is assumed that there are no elements that do not belong to either set A or set B. In the language of logic algebra, this means that the disjunction of A and B is true ($A \vee B = 1$).

Decision. We will determine which part of the elements fails due to the increase in temperature and increased vibrations, that is, we will find the intersection of the sets A and B (the conjunction $A \wedge B$)

$$A \wedge B = A + B - A \vee B = 0{,}7 + 0{,}6 - 1 = 0{,}3.$$

Let's find out which part of the elements fails only due to an increase in temperature

$$A \wedge B = A - A \wedge B = 0{,}7 - 0{,}3 = 0{,}4.$$

Let's determine which part of the elements fails only after the vibrations increase

$$A \wedge B = B - A \wedge B = 0{,}6 - 0{,}3 = 0{,}3.$$

A condition is a form of thinking or a logical action, as a result of which one or more judgments known to us and connected in a certain way (called links) result in a new judgment in which new knowledge is contained.

For example, if there are two references: "All liquids are elastic" and "Water is a liquid", then the conclusion can be drawn from them: "Water has elasticity."

Thus, in the process of inference, new knowledge was obtained, while it was impossible to derive this new knowledge from any of the original judgments taken separately.

The main laws of mathematical logic, the use of which allows the researcher to make correct judgments and true conclusions, are four laws [14].

1. The law of identity is a universal law of the correct construction of thoughts in the reasoning process, discovered by Aristotle three and a half centuries before our era, which has great practical significance.

The law of identity is symbolically written as A = A, that is, A is identical to A, or A is A.

This means that the content and scope of the considered concept remain unchanged. In particular, when conducting scientific research and experiments, their object must remain unchanged.

Strictly speaking, this requirement is almost impossible, because any research object is exposed to an infinitely large number of factors that are constantly changing.

However, this implies that the main and essential features and properties of this object change within acceptable limits.

This assumption allows us to observe the law of identity.

The law of identity cannot be interpreted in the sense that any concept must forever retain its once defined meaning.

The content of the concept can change in connection with the change of the subject reflected in this concept; new sides, more significant features in the subject under study may be revealed.

However, after it has been established in what relation this concept is thought in the whole process of this reasoning, this concept must be taken in one meaning, otherwise there will be no certainty, connection and consistency in our reasoning.

2. The law of contradiction means that it is impossible for the same sign to occur and not occur at the same time, under the same conditions.

Symbolically, this law is written as $A \wedge A = 0$ and reads as "For any A, the statement A and the negation of the same A cannot be true at the same time."

3. The law of exclusion of the third is formulated as follows: with two judgments, one of which affirms what the other denies, there cannot be a third judgment.

Either A is true and then it is false, or it is true and A is false.

Symbolically, this law is written in the form $A \vee A= 1$, wehere «$\vee$» – symbol meaning "A or , but not both together."

The following rule follows from this law: if one of the judgments is rejected, the opposite should be accepted.

4. The Law of Sufficient Basis: an opinion is true if and only if there is a sufficient basis, which is understood as true, previously proven propositions or givens of experience.

In other words, every true opinion must be substantiated by other opinions whose truth is sufficient.

Symbolically, the law of a sufficient basis is depicted by the formula: "If there is A, that is, its basis is B."

The requirement for the validity of thinking reflects one of the fundamental properties of the material world.

In nature and society, every fact, every object, every phenomenon is prepared by previous facts, objects, phenomena.

No phenomenon in nature and society can appear if it is not prepared; if it has no cause in previous material phenomena.

It is important to note that the requirements of the Law of Sufficient Basis also apply to the learning process. Aristotle spoke about this in one of his works: "All knowledge and all learning is based on some previously existing knowledge."

With the help of logic, thinking processes are built, in which the following types are distinguished: theoretical, intuitive and practical.

The great value of heuristic methods of creativity lies in the fact that they allow solving problems in the conditions of incompleteness of the original information, when these or other investigated processes or phenomena cannot be described quite clearly and closed logically.

The most widespread heuristic creativity technologies are: trial and error methods; "brainstorming" method; collective search for new ideas; method of synectics; method of morphological analysis; functional and cost analysis; the method of control heuristic questions.

Heuristic methods do not exclude, but assume the possibility of heuristic planning, the use of information and search systems, personal computers when solving variational decision-making problems.

Algorithmic (computer) methods of finding new ideas for technical solutions are often called "intellectual", "logical", "machine" in literary sources.

Control questions and tasks for independent preparation

1. Define logic and intuition.
2. What methods of cognition include logical thinking and intuition?
3. Name the five most common logical operations.
4. Describe the laws of mathematical logic: identity, contradiction, exclusion and sufficient basis.
5. Name the main heuristic technologies of creativity.
6. Tasks for independent solution. The technical device consists of a group of elements, among which it was found that 10% of the elements fail due to an increase in temperature and 50% - due to increased vibrations. By adding your serial number in the teacher's electronic journal to the given problem data, determine what part of the elements fails as a result of increased temperature and increased vibrations?

LECTURE OUTLINE 11

PLAN

11.1 Trial and error methods

The method of trial and error is the oldest method of invention and search for new technical solutions. This method of randomly searching for options does not contain any rules for generating and evaluating ideas.

The key to solving the problem can be any idea that came to the mind of the developer thanks to a lucky chance or intuition.

The path to an ideal technical solution using this method is time-consuming and unproductive, because as a result of evaluating one unsuccessful idea, another new idea is put forward instead of it, and everything is repeated many times until an acceptable solution is found.

However, even great inventors and scientists successfully used this method and achieved great success in shipbuilding, aircraft, automobile construction, house construction, etc.

The method of trial and error mobilizes the creative capabilities of a person, but it is not protected from the psychological inertia of the intellect.

It is advisable to use it when solving problems with a small (no more than 20) number of options.

When solving problems of great complexity, it becomes ineffective.

The technique of activating a person's creative activity can be the use of known works of ideas, which will exclude the return to the same ideas.

11.2 Associative methods

So-called associative methods (analogies, focal objects, garlands of cases and associations) are used to intensify the search for new ideas.

The process of finding new ideas using associative methods is carried out by searching for analogs of the object being improved, transferring knowledge from one area to another, interpreting the new using known concepts, etc.

In this regard, such sources of generating new ideas as associations, metaphors and analogies are quite effectively used in the creative process.

An association is a connection between separate representations in which one representation causes another.

Metaphor means transferring the properties of one object (phenomenon) to another object on the basis of a feature common to both. It plays an important role in building an imaginary image and model of reality by assimilating a new, unknown or complex object (phenomenon) to an already familiar or simpler one.

The unusualness, novelty, and originality of the researcher's attitudes determine the processes of images, models, abstractions, and constructions.

Analogy reflects the similarity of objects, phenomena, processes in some properties.

Associations can be identified by similarity; by color, which exerts a psychological influence on a person; by contrast, for example, classic-modern, fashionable-old-fashioned.

Sometimes the analogy is obvious, and sometimes it covers essential connections that are not obvious and can be established by means of complex abstractions.

Analogy is based on the comparison of objects mainly of the same nature.

Conclusions by analogy belong to the class of probabilistic conclusions. Therefore, it is considered that their evidentiary value is small.

However, it should be borne in mind that inferential operations of this type can get a proper assessment only in a fairly broad context of specific circumstances that can significantly increase or decrease the probability of the conclusion.

Conclusions by analogy can give reliable results, in particular, if there is a relationship of isomorphism or homomorphism between the compared systems.

Systems are called isomorphic only when each element, property or relation of one system corresponds to a single element, property or relation of another system, and vice versa.

Systems are called homomorphic if each element, property, or relation of one system corresponds to a single element, property, or relation of another system, but not vice versa.

Associative methods are based on the ability of the brain to establish certain connections between words, concepts, and thoughts, and then recall and restore such connections.

The essence of associative thinking is that memories, impressions, not directly related to the subject under consideration, are able to cause thoughts and their chains, which close the bridge between these memories and the expected task and are able to lead to unexpected new ideas.

It is interesting that a task that has stuck in the mind usually attracts and brings back to itself chains of associations that develop again.

Moreover, they can arise and develop subconsciously, and only a ready answer appears in consciousness [10-13].

The conscious inclusion of associative thinking is achieved by creating appropriate conditions and using a number of rules, which together form the basis of the most widespread and practice-tested similar methods of creativity.

The use of associations, metaphors and analogies helps to find clues to the solution of various engineering problems.

This property of associations, metaphors and analogies served as the basis for the creation of associative methods of activation of creative thinking.

The method of focal objects belongs to associative methods. The name of the method is explained by the fact that the subject (object) that is being improved is, as it were, taken into the focus of our attention.

The idea of the method is that when the characteristics of other, randomly selected objects are transferred to the object being improved, the number of unexpected solution options increases dramatically.

The method gives good results when searching for new modifications of known objects, devices, methods, as well as when searching for new model solutions, expanding functional capabilities, training creative imagination.

The method of garlands of cases and associations was proposed by

G. Bush [2, 3].

Garlands of cases are formed in the form of a list of synonyms or associations. Then the elements from different garlands are combined in pairs.

Associative methods of activation of creativity are universal. They are applicable in technology, science and management.

The method of garlands of associations can be applied when new properties are to be added to the design object.

To do this, synonyms are selected for its name (if possible), and then other objects are randomly named and combinations of those and others are made.

Each combination is complemented by one or another feature of a random object or the associations it causes.

The main content of the method is to "shake up" the stereotypical idea of the object, to overcome the inertia of thinking.

The general drawback of associative methods of activation of creativity is their relatively low efficiency.

11.3 The Delphi method

The name of the method is conventional and is associated with the ancient Greek city of Delphi [11].

In contrast to the "brainstorming" method, it can be called an independent intellectual experiment, since each expert expresses his opinion independently of the opinion of his colleagues.

At the same time, the isolation of experts is encouraged, the professional secrecy of the written dialogue between the forecaster and each expert is observed, which helps to exclude the influence of authorities and "pressure" on the expert.

There are four main varieties of the Delphi method: simple ranking (method of preference), assignment of weighting coefficients, sequential comparisons, pairwise comparisons.

The simple ranking method is that each expert is asked to rank the features in order of preference.

The method of assigning weight coefficients is the assignment of weight coefficients to each of the features, which can be presented in two ways: all features are assigned weight coefficients so that the sum of the coefficients is equal to some fixed number (for example, one, ten, one hundred).

To the most important of all signs, a weighting factor equal to some fixed number is added, and to others - factors equal to fractions of this number.

The method of paired comparisons is used when there are a large number of alternatives. According to this method, all characteristics are compared in pairs and based on the evaluations of pairwise comparisons, through further processing, the evaluation of each characteristic is found.

To facilitate the procedure of pairwise comparison of features, a matrix table of pairwise comparisons is usually compiled.

Currently, the Delphi method is an iterative procedure that allows each expert's opinion to be subjected to critical analysis by all others.

We will give a practical example from work [11].

Suppose, a group of experts, consisting of 12 specialists, is given the task of estimating the duration of a certain measure, for example, the transition of a fleet of cars to gas fuel.

The procedure for using this method is as follows:

1) the head of the examination individually sets the task for the experts and receives their evaluations, i.e. the duration of the event implementation;

2) when processing, expert assessments are arranged in ascending order, for example, table 11.1;

3) quantiles Q1, Q2, Q3 are applied to the rating scale in such a way that the number of experts and ratings is divided into four equal parts. At the same time, M is the median value of the results of the expert survey, which divides them into two equal parts.

Sometimes it is accepted as an estimate $Q_1=\bar{x}$-S (instead Q_1), $M=Q_2=\bar{x}$, $Q_3=\bar{x}$+S (instead Q_3);

4) after data processing, each member of the group is individually notified of the following results of the first round: Q1=12.5, M=16, Q3=19.5 months. and it is suggested to revise his assessment in the second round, and if the new assessment is greater than Q3 = 19.5 or less than Q1=12.5, the expert is recommended to justify his opinion in writing;

5) the results of the second round are determined and the new values of Q1, M, Q3 are reported to all experts.

As a rule, after each round, the variance of the estimates decreases. Usually, the procedure continues 3-4 times, after which the experts' arguments are repeated, and the variations in the estimates stabilize.

Table 11.1 – Procedure for applying the Delphi method

№ expert	Evaluation by experts, months
E9	10
E7	11
E5	12
	$Q_1=\bar{x}$-S=12,5
E6	13
E12	14
E10	16
	$M=Q_2=\bar{x}=16$
E4	19
E3	20
E11	21
	$Q_3=\bar{x}$+S=19,5
E1	22
E2	24
E8	25

The median of the final round is taken as the group opinion. The accuracy of the Delphi method increases with the increase in the number of experts and the number of iterations, and decreases with the increase in the time interval between rounds and group members' responses.

Control questions and tasks for independent preparation

1. Unlike the "brainstorming" method, the Delphi Method can be called an independent intellectual experiment, because ...?
2. Which random search method does not include any rules for idea generation and evaluation?
3. Is the statement true: The key to solving a problem can be any idea that came to the mind of the developer through luck or intuition?
4. Is the statement true: The method of trial and error mobilizes the creative capabilities of a person, but it is not protected from the psychological inertia of the intellect?
5. With how many options for solving problems is it advisable to use the trial and error method?

6. By what properties does Analogy reflect the similarity of objects, phenomena, processes?

7. Task. Applying the Delphi method and using the initial data obtained by adding to those given in the table. 11.1 of its serial number in the electronic journal, provide an estimate of the duration of the implementation of the specified measure - the transition of the fleet of passenger cars to gas fuel.

LECTURE OUTLINE 12

PLAN

12. Heuristic methods of finding ideas and solving scientific and technical problems. Modifications of the "brainstorming" method.
12.1. Brainstorming method
Control questions and tasks for independent solution

The "brainstorming" method is also called the "brain attack" method. This is one of the most widespread methods of psychological activation of creative activity, generation of new ideas through creative cooperation of a group of interested participants.

It is based on such a psychological effect.

Suppose there are 5-8 people in the creative group of developers of some technical object.

If each person from this group is offered individually and independently of each other to express ideas and proposals for the solution of some task of creating a new technical object, then in total N ideas can be collected.

If this group of people, the number of which will be denoted by the letter K, will express ideas on the solution of the same problem collectively, together, then as a result Nk ideas will be collected, and the number of Nk always turns out to be much larger (Nk >> N).

Usually, experienced professionals generate and express no more than 10-20 ideas in 15-30 minutes of individual (isolated from others) work, and in collective work (following certain rules), the group generates 50-150 different ideas in the same time.

Psychologists believe that during a "brainstorming" session, a chain reaction of ideas occurs, leading to an intellectual explosion.

Brainstorming organizes a collective search for technical solutions. It is usually conducted by people who are not trained in special creative techniques.

The manager gathers a group of specialists, usually no more than ten people, and sets a task for them.

Each participant of the "brainstorming" session, which lasts no more than 1 hour, can express any ideas.

Analysis and criticism of them during the session is not allowed.

The main motto of the method is: "The more ideas, the better."

If during the session, in the opinion of the leader, few ideas were expressed, it can be repeated, perhaps with a different composition of participants.

All utterances are fixed in a certain way.

The method of "brainstorming" ("attacks") is often divided into: direct "brainstorming", double "brainstorming" with several discussions of the same problem, mass "brainstorming" with the number of audience participants from 20 to 60 people, reverse "brainstorming" » with the compilation of a complete list of shortcomings and clarification of the statement, development of the technical task and examination; evaluation of the effectiveness of decisions taken at the stage of creation and start of operation of the technical system.

The method of "brainstorming" ("attack") is described in works [1-3, 10-13]. We will give examples of the use of "brainstorming" to activate creative activity.

"Brainstorming" method. The method and term "brainstorming" or "brainstorming" was proposed by the American scientist A. Osborn as an improved version of the Socratic dialogue with the wide use of free associations, while simultaneously creating a psycho-heuristic microclimate in small groups of people to increase the efficiency of solving creative, especially inventive tasks .

A. Osborn believed that all people have creative abilities, but they slumber under the oppression of the attitude of "impossibility to act", the inability to correctly formulate and formalize the idea of a solution.

The heuristic dialogue of "brainstorming" is based on a number of psychological and pedagogical regularities, but before formulating them, it is worth briefly dwelling on the theoretical premises that guided the creators of this method.

The inventors noted that it is more effective to generate ideas collectively than individually.

Under normal conditions, a person's creative activity is often restrained by explicitly and implicitly existing barriers (psychological, social, pedagogical, etc.).

It is convenient to express this situation using the "gateway" model.

In this model, creative activity is likened to the energy of water held back by a sluice. Therefore, you need to open a "gateway" to release this activity.

A firm management style, fear of mistakes and criticism, a purely professional and too serious approach to business, the pressure of the authority of more capable specialists, traditions and habits, lack of positive emotions - all this acts as a "gateway".

Dialogue in the conditions of a "brain attack" acts as a tool that allows you to destroy the "gateway", to release the creative energy of the participants in solving a creative task.

At this time, several modifications of the "brainstorming" method were developed.

Direct "brain attack". One of the most widespread methods of activating creative activity is the use of the so-called "brainstorming".

This method was introduced into the practice of inventive activity by A. Osborn.

However, this does not mean that people did not use similar techniques for finding new solutions long before Osborne.

Back in the days of Columbus, there was a tradition according to which, in the event of an extreme situation on a ship, a council was convened to adopt an action plan, to which all crew members were invited without exception.

The captain listened to the opinions of everyone who had gathered, starting with the young man and ending with his assistants, and then made a decision.

This procedure was established so that the suggestions of senior team members did not put pressure on junior ones.

"Brainstorming" as a method that does not require special training of the participants, is most often used by teachers in technology classes when performing projects.

Unfortunately, not all teachers understand that not every collective discussion of a new idea is a "brainstorming".

"Brainstorming", like any other method of finding new solutions, has its own purpose and methodology.

The purpose of "brainstorming" is to obtain the maximum number of new ideas by mutually stimulating group members to intensive intellectual search.

The advantage of the method lies in the unlimited range of problems to which it can be applied: with the help of the "brainstorming" method, any problem can be considered if it is sufficiently simply and clearly formulated.

This method is used at any stage of design, both at the beginning, when the problem is not yet fully defined, and later, when complex subproblems have already been identified.

It can also be used to generate information rather than ideas, i.e. to find out sources of information or formulate questionnaire questions [5].

Another advantage of the method is that minimal preliminary training is required from the participants of the brainstorming session.

In some cases, it is useful to involve people who have never before dealt with the issues under discussion.

The plan of action is as follows.

1. Select a group of people to generate ideas.

2. Introduce a rule that prohibits criticizing any idea, no matter how "wild" it may seem, and make the participants aware that any ideas are accepted, that it is necessary to get many ideas and that the participants should try to combine or improve ideas, suggested by others.

3. Record the proposed ideas and then rate them.

In the literature [2, 12], it is recommended, in addition to the group of "generators" of ideas, to immediately involve a group of experts in the "brainstorming".

Another group - experts - makes a collective judgment about the value of the proposed ideas.

The optimal number of the group of "generators" of ideas is 7-12 people.

The number of the group of experts may be smaller.

The idea of simultaneously forming groups of "generators" and experts is very correct. Participation in the group of "generators" of a person oriented only on criticism can disorganize the work of the group. Therefore, it is advisable not to remove all "critics" from work, which is especially difficult to do in a class or student group, but to concentrate them in a group of experts.

You can transfer the function of recording the ideas expressed during the brainstorming session to a group of experts so as not to distract the generators from recording them.

A dictaphone or video recording of the session is also acceptable.

Some people who are "generators" by nature, but shy to express their ideas in front of a large team. To use the potential of such people, the so-called shadow "brain attack" is used.

At the same time, next to the usual group of "generators" a shadow cabinet is formed, which works simultaneously with the first group, but whose members do not express their ideas out loud, but record them on paper.

Active and shadow groups are placed in the same room at a certain distance. They can be in different rooms, and the connection between them is established using a video monitor.

There is also the experience of "brainstorming", in which the members of the shadow cabinet were the viewers of the TV program, who sent their decisions to the editors of the program after the program ended.

The effectiveness of the "brain attack" can be increased by informing the "generators" in advance of the essence of the discussed problem.

Regardless of whether the "generators" will specifically think of ways to solve the problem communicated to them, the search for a solution will take place at the subconscious level.

The success and effectiveness of any "brainstorming" depends to a very large extent on the presenters (chairman of the meeting), who carry out operational management of the brainstorming.

Throughout the brainstorming session, he should maintain a relaxed atmosphere and encourage the participants.

In addition, he has the following duties [7]:

1. At the beginning of the session, the presenter should introduce all the participants (if the group is meeting for the first time), giving them a short positive description. He then lays out the rules for the session participants.

2. The leader presents the wording of the problem both in a special and in a generally accessible form. At the same time, it is necessary to force the participants to perceive the task as their main problem, reinforcing the formulation of the task with expressions such as: "Imagine yourself in the place of such and such a person." "What would you do if you were in charge of this case?"

3. The presenter must be able to ensure that the participants observe all the rules of the brainstorming session, without using critical remarks.

4. The presenter should ensure the continuity of the expression of ideas, filling the pause with encouraging remarks, for example:

"At one time, this and that were offered";

"Let's express only absolutely fantastic ideas for three minutes";

"What does (student's name) think about this?";

"How to solve this problem, if you remove such and such a condition?";

"We have already expressed 37 ideas, let's reach 40!";

"How would we solve the problem if we had a million dollars?".

5. The presenter should ensure that the discussion does not go too narrowly or in too pragmatic a direction.

With his replicas, he should expand the scope of the search.

For example, if there is a discussion about which semiconductor device products can be created, then the discussion cannot be allowed to come down to specifying the design or number of devices used.

6. The presenter must follow the work schedule. Tell how much is left until the end of the work.

It is tactical to stop a participant who formulates one idea for too long (more than half a minute).

Brainstorming is an intense, fast-paced creative process. Therefore, there cannot be a single definitive scheme for conducting a "brainstorming session".

Each team of "generators" and the host create their own individual style during the work, which allows interaction with the greatest efficiency.

In conclusion, it should be noted that if there is time for the preparation of the participants, it is worth working out with the creative group or with its core the technique of brainstorming in training sessions.

At the same time, educational tasks have:

be understandable to all participants;

contain a potentially large number of possible solutions;

arouse the interest of all participants.

In the course of brainstorming, ideas can be expressed that can become the basis of innovative proposals or applications for inventions.

Therefore, after the end of the brainstorming session, it is advisable to clarify and determine the list of authors of the most interesting ideas and agree on it with the entire creative group that participated in the session.

Double "brain attack". The idea of more effective use of the possibilities of the subconscious is embedded in the double "brain attack" method.

People long ago noticed the expediency of holding several discussions of the same problem and formulated this wisdom in the "winged" expression: "Good thinking comes later."

The essence of the double brainstorming method is to conduct it some time after the first, repeated "brainstorming".

As the practice of using this method has shown, during repeated brainstorming, more interesting and deep ideas are often expressed than during the first discussion.

This is caused by the intensive work of the brain at the subconscious level in the period between discussions.

This period can vary widely - from several hours to several days.

Experienced administrators often do not know about the existence of the double "brainstorming" method, but use it in their work.

For example, they hold individual discussions of a problem with members of the administrative council on the eve of a meeting where decisions on complex issues are supposed to be made.

Similar goals are achieved by pre-distributing meeting agendas and draft decisions among board members.

Mass "brainstorming", proposed by Donald Phillips (USA), allows to significantly increase the efficiency of generating new ideas in a large audience (the number of participants varies from 20 to 60 people).

The peculiarity of this modification of the method is that the participants are divided into small groups of 5-6 people.

The leader of each group is also the leader of the entire session.

After dividing the audience into small groups, each one conducts an independent session of direct brainstorming.

The duration of work of small groups can be different or fixed, for example, 15 minutes.

After generating ideas in small groups, they are evaluated.

Then they choose the most original one.

The reverse "brainstorming" method is widely used in creative activities. It is based on the regularity of the progressive constructive evolution of technical objects, according to which the transition to new models occurs by identifying and eliminating already existing flaws (contradictions).

The tasks of technical system development require the elimination of emerging contradictions.

Different kinds of contradictions may not manifest themselves in an obvious form and because of this may fall out of the field of view of the developers of new systems at the stage of their creation.

In addition, a number of contradictions may appear only after some time after the start of operation of the system.

Therefore, when creating a new system or a separate product, two creative tasks are solved:

1. Existing or expected contradictions in the existing system or

technical object are revealed.

2. There are ways to eliminate these shortcomings in newly created systems and objects.

The first task turns out to be no less simple than the second, since the methods of solving it should ensure not only the detection of all known, but also the prediction of all future shortcomings.

In other words, a complete list of shortcomings (regardless of the cause of their occurrence) should reflect all possible deviations of the actually existing position from the desired one.

To solve this problem, the domestic researcher E.O. Aleksandrov proposed a reverse brain attack method, which was further modified by G.Ya. Bush.

This method is sometimes called a dialogue with destructive relative evaluation [13].

The reverse brainstorming method can be used when solving, for example, accompanying questions and problems:

clarifying the setting of inventive and rationalizing tasks;

development of a technical task or a technical proposal;

project expertise at any stage of development;

evaluation of the efficiency of purchased products;

assessment of the effectiveness of administrative decision-making.

The effectiveness of reverse brainstorming largely depends on the clarity of the problem formulation.

The formulation of the problem for reverse brainstorming should contain short and fairly comprehensive answers to the following questions:

What is the system that needs to be improved?

What shortcomings of the system related to its production, operation, operation, maintenance and disposal are already known?

What should be obtained as a result of "brainstorming"?

What should you pay special attention to?

If the wording of the problem contains very special terms that are not clear to the participants of the discussion, it is necessary to make a second publicly available version of the previous wording - without special terms.

In some cases, a combination of direct and reverse "brainstorming" methods turns out to be the most effective.

Such a combination can be used, for example, to forecast the development of technology (and not only technology).

To do this, with the help of a reverse "brain attack", all the shortcomings of the existing product or system are identified and the main ones are identified among them.

Then they conduct a direct "brain attack" with the aim of eliminating the identified main shortcomings and outline ways to improve the objects of this class.

To predict the shortcomings of a technical object, a direct reverse brain attack is first conducted and projects of the most promising solutions are prepared, and then it is conducted to identify possible shortcomings of these solutions.

The following procedures are expected to be carried out in stages:

formation of small groups, optimal in terms of number and psychological compatibility;

creation of a group to analyze the problem situation, formation of the original inventive task in a general form, notification of the task together with a description of the relatively destructive assessment to all participants of the dialogue;

generation of ideas according to the rules of direct collective "brainstorming" (special attention is paid to creating a creative, relaxed atmosphere);

systematization and classification of ideas. Features that can be used to combine complex ideas are studied, and according to these features, ideas are classified into groups:

destructuring ideas, that is, evaluating ideas for the possibility of implementation in the process of "brainstorming". "Brainstorming" at this stage is aimed only at a comprehensive consideration of possible obstacles on the way to the implementation of the proposed ideas;

evaluating the critical comments made during the previous phase and drawing up a final list of practical ideas. Only those ideas that were not rejected as a result of critical remarks and counter-ideas are included in the list.

The most effective results are achieved in cases where all participants of the "brain attack" are rationally divided into the following groups: generation of ideas; analysis of the problem situation and evaluation of ideas; generating counter-ideas.

The term "brain attack" seems to us not entirely successful, since "brain" is a physiological concept, and "attack", "assault" are concepts borrowed from the military lexicon.

V. Andreev believes that, from a pedagogical point of view, it is more appropriate to call this method a "method of collective search for original ideas."

The method of collective search for original ideas is based on pedagogical laws and their corresponding principles:

co-creation (cooperation) of the teacher and students. The teacher, relying on a democratic style of communication, encouraging imagination, unexpected associations, stimulates the emergence of original ideas and acts as their co-author. The more developed the teacher's abilities for cooperation (co-creation), the more effective, under other conditions, are the methods of solving creative problems by his students;

confidence in the creative forces and abilities of students. All students act as equals: with a joke, a successful retort, the teacher encourages the greatest creative initiative of his students;

optimal combination of intuitive and logical.

In the conditions of generating ideas, it is optimal to weaken the activity of logical thinking and all kinds of encouragement of intuition. This is greatly facilitated by rules such as the prohibition of criticism, delayed logical and critical analysis of generated ideas.

A friendly pedagogical microclimate creates conditions for relaxation, activates intuition and imagination.

The disadvantages and limitations of the method consist in the fact that its application allows you to propose and find a creative idea only in the most general form.

The method does not guarantee thorough development of the idea. It is also inapplicable or has limitations in its application if the creative task requires large preliminary calculations, calculations.

Application of the method of collective search for original ideas requires relatively high pedagogical skills, improvisation skills, and a sense of humor.

In the process of its application, an illusion is sometimes created of some most likely means, technique, approach to solving a creative problem.

The logic of group thinking is most often directed in this direction, but this most obvious approach to problem solvers sometimes turns out to be wrong.

In the table 12.1 gives the basic rules for applying the method of collective search for original ideas (including technical ones) proposed by V. Andreev.

Table 12.1 - Heuristic rules for applying the method of collective search for ideas

For the teacher	For students
Class students are divided into small study groups of 5-7 people: a) idea generation group; b) critical analysis of proposed ideas; c) protection of criticized ideas; d) final evaluation of the proposed ideas. It is possible that all students of the class gradually perform all the above-mentioned functions of solving a creative problem sequentially	Start the discussion of the problem with distant approaches, it is desirable to reformulate it several times
Strive for a friendly, democratic style of communication, and for this it is necessary to give all students equal rights to express any ideas, think aloud, use an appropriate line, joke	It is advisable to record the proposed ideas, for example, write them down in a notebook, on the board or using a recorder.
Constantly encourage and guide the flow of the discussion, involving all its participants in the solution of the creative problem	At the stage of generating ideas, any criticism is prohibited
At the first stages (generation of ideas), none of the students has the right to criticize proposals, proposed ideas, express ironic remarks. The teacher must strive for an absolute ban on criticism	Be kind to each other, do not forget that a sense of humor and positive emotions stimulate imagination and imagination well

Continuation of table 12.1

<table>
<tr><td>In the process of generating ideas, constantly encourage and guide the course of the discussion, encourage students to find analogies, combine or, on the contrary, separate elements, intensify or, on the contrary, slow down the analyzed processes, search for all new functions of the object, etc.</td><td>Use analogies, try to combine or, on the contrary, separate elements, intensify or slow down the analyzed process, etc.</td></tr>
<tr><td colspan="2">At the stage of criticism of ideas, any form of their protection is prohibited. The author of the expressed idea must himself express an opinion about its shortcomings</td></tr>
<tr><td colspan="2">At the final stages of the discussion, criticism is prohibited again, only proposals are made in favor of concretization, development of the most original idea, proposals for its practical implementation</td></tr>
<tr><td colspan="2">The general summary of the proposed ideas, generalizing critical remarks is summarized by the teacher</td></tr>
</table>

Control questions and tasks for independent preparation

1. What is the psychological effect of the "brainstorming" method?
2. In what number and by what specialties is the group recruited for the collective search for technical solutions?
3. What varieties of the "brainstorming" ("attack") method do you know?
4. Which of the scientists proposed the method of "brainstorming" or "brainstorming" with the simultaneous creation of a psycho-heuristic microclimate in small groups of people to increase the efficiency of solving creative, especially inventive problems?
5. Is the statement true: The goal of "brainstorming" is to obtain the maximum number of new ideas by mutually stimulating group members to intensive intellectual search?
6. What is the advantage of the "brainstorming" method?
7. Why is it sometimes useful to involve people who have never dealt with the discussed issues before?
8. What is the plan of action during "brainstorming"?
9. On whom does the success and effectiveness of any "brain attack" depend?
10. What are the responsibilities of a brainstorming leader during a session?

11. If there is time to prepare the participants, is it necessary to work out the brainstorming technique with the creative group or with its core?

12. What educational tasks are carried out at educational and training sessions with a creative group on brainstorming techniques?

13. What regularity is the basis of the reverse "brainstorming" method?

14. What creative tasks are solved when creating a new system or a separate product?

15. Which of the scientists proposed the reverse "brain attack" method, which was further modified by G.Ya. Bush?

to solve the specified problem by the domestic researcher E.O. Oleksandrov was offered.

16. What is the reverse "brainstorming" method sometimes called?

17. What procedures are supposed to be performed step by step for predicting the shortcomings of a technical object after conducting a direct reverse brain attack?

18. On what pedagogical regularities and their corresponding principles is the method of collective search for original ideas based?

19. Tasks. Using the heuristic rules of applying the method of collective search for ideas according to V.I. Andreev, presented in the table. 12.1, to come up with an idea for the implementation of the specified measure - the transition of the passenger car fleet to gas fuel.

LECTURE OUTLINE 13

PLAN

13. Heuristic methods of finding ideas and solving scientific and technical problems. Method of control questions
13.1 Method of control questions
Control questions and tasks for self-study

The method of control questions consists in finding solutions to the problem using a specially prepared list (list) of leading questions.

There is a wide variety of checklists from very simple to quite complex. The abundance of questions on the list does not mean that the answer to each of them should lead to a new idea.

The hope is that when answering the questions, that "enlightenment" will come, which will lead to the desired idea of solving the problem.

The method can be applied either in the form of a monologue of a specialist addressing himself, or in a dialogue, for example, in the form of questions asked by the head of a brainstorming session to members of a group of idea generators.

Depending on the specifics of the object in question or the goals of the analysis, the questions can be very diverse - from very simple to quite complex.

The large number of questions on the list does not mean that the answers to each of them should lead to a new idea.

If at least one interesting idea is obtained as a result of searching for a solution using this method, it can be considered that the questioner has completed his task.

Some lists do not contain questions, but short recommendations, others have both.

There is a wide variety of checklists. However, universal questionnaires compiled by A. Osborn and T. Ailoart [1-3, 10-13] are used more often than others.

The list of control questions according to A. Osborn contains nine groups of questions:

1. What new application of the technical object can you propose? Are new ways of application possible? How to modify known methods of

application?

2. Is it possible to solve the inventive problem by adaptation, simplification, reduction? What does this technical object remind you of? Does the analogy lead to a new idea? Have there been similar problematic situations in the past that can be used? What can be copied? What technical object should be overtaken?

3. What modifications of the technical object are possible? Is it possible to modify by rotating, bending, twisting, turning? What changes in purpose (function), color, movement, smell, shape, outlines are possible? Other possible changes?

4. What can be increased in the technical object? What can be attached? Is it possible to increase the service time, influence? Increase frequency, size, strength? Improve quality? Add a new ingredient? Duplicate? Is it possible to multiply work items or the entire object? Is it possible to exaggerate, hyperbolize elements or the entire object?

5. What can be reduced in a technical object? What can be replaced? Can anything be compacted, compressed, condensed, condensed, miniaturized, shortened, narrowed, separated, shredded?

6. What can be replaced in the technical object? What, how much to mix and with what? Another ingredient? Another material? Another process? Another source of energy? Another location? Different color, sound, lighting?

7. What can be transformed in a technical object? What components are interchangeable? Change model? Change the layout, layout, layout? Change the sequence of operations? Transpose cause and effect? Change speed or pace? Change mode?

8. What can be turned upside down in a technical object? Transpose positive and negative. Can oppositely placed elements be swapped? Turn them backwards? Turn upside down? Swap places? Switch roles? Reverse the clamps?

9. What new combinations of technical object elements are possible? Is it possible to create a mixture, an alloy, a new assortment, a set? Combine sections, nodes, blocks, aggregates? Combine goals? Combine attractive features? Combine ideas?

The list of control questions compiled by T. Ailoart represents the work program of a talented inventor, determined by questions and tasks that require a developed imagination and deep versatile knowledge.

In essence, he gave the program of work of a talented inventor with fanatical persistence, trying to solve a problem by trial and error.

Some questions require a developed imagination, others - deep and versatile knowledge. There are also questions that are very subtle in their own way, which testifies to T. Ailoart's rich experience and observation.

List of control questions according to T. Ailoart:

1. List all the qualities and definitions of the proposed invention. Change them.

2. Formulate tasks clearly. Try new formulations. Identify secondary and similar tasks. Highlight the main ones.

3. List the shortcomings of existing solutions, their main principles, new assumptions.

4. Sketch fantastic, biological, economic, molecular and other analogies.

5. Build mathematical, hydraulic, electronic, mechanical and other models (they express the idea more accurately than analogies).

6. Try different types of materials and energy: gas, liquid, solid, gel, foam, paste, etc.; heat, magnetic energy, light, impact force, etc.; different wavelengths, surface properties, etc., transition states - freezing, condensation, transition through the Curie point, etc.; Joule-Thompson, Faraday, etc. effects.

7. Establish options, dependencies, possible connections, logical relationships.

8. To find out about the opinion of some completely ignorant people in this matter.

9. Have a chaotic group discussion, listening to all ideas without criticism.

10. Try "national" solutions: cunning Scottish, comprehensive German, wasteful American, complex Chinese, etc.

11. Sleeping with a problem: going to work, walking, taking a shower, driving, drinking, eating, playing tennis - everything with it.

12. Wander among the stimulating environment (junk dump, technical museums, thrift stores), browse magazines, comics.

13. Sketch a table of prices, quantities, movements, types of materials, etc. different solutions to the problem in solutions or new combinations.

14. Determine the ideal solution, develop possible ones.

15. Change the solution of the problem in terms of time (faster or slower), dimensions, viscosity, etc.

16. Imagine climbing inside the mechanism

17. Identify alternative problems and systems that remove the

specified link from the chain and, thus, create something completely different, leading away from the desired solution.

18. Whose problem is this? Why him?

19. Who invented it first? History of the question. What misinterpretations of this problem have occurred?

20. Who else solved this problem? What did he achieve?

21. To determine generally accepted boundary conditions and the reasons for their establishment.

It is worth noting that the ancient Roman philosopher Quintilian used heuristic questions widely in his scientific and practical activities.

He recommended that his students, in order to gather sufficiently complete information about any event, ask themselves and answer seven key, or heuristic, questions: who? what? why? where? what? how? When?

The American mathematician and teacher D. Poya paid a lot of attention to heuristic questions, whose research became the basis of the rules and systematization of heuristic questions.

D. Poya's list was created mainly for solving educational mathematical problems, but it can also be used for solving technical ones.

List of heuristic questions V.I. Andreeva, compiled on the basis of the recommendations of D. Poya [2], stimulates the solution of creative problems:

1. It is necessary to clearly understand the proposed task, and for this it is necessary to ask oneself a number of questions and tasks: what is unknown? what is given what is the condition? is it possible to satisfy the condition? are there enough conditions to find out the unknown? or not enough? or excessively? or contradictory? make a drawing; enter a suitable designation; divide the condition into parts; try to write them down.

2. At the stage of searching for ideas and drawing up a solution plan, the following heuristic questions are asked: how to find the connection between data and unknowns? Do you know of any close task? can't you use it? is it possible to use the method of its solution? shouldn't we introduce some helper to take advantage of the former task? Is it possible to formulate the problem in a different, simpler way? can you think of a more accessible task? more general? more detached? similar task? is it possible to solve part of the problem, satisfy part of the conditions? Can anything useful be extracted from the data? Have you used all the terms and conditions? Are all concepts included in the problem taken into account?

3. When implementing a solution plan, monitor each step you take: is it clear to you that the step you started is the right one? can you prove that he is right?

4. Control and self-control of the obtained solution involves searching for answers to the following questions: is it possible to check the result? is it possible to check the progress of the solution? Is it possible to get the same result differently? Is it possible to check the plausibility and dimensionality of the obtained result? is it possible to use the obtained result in any other problem? is it possible to solve the inverse problem of this one?

List of universal questions G.Ya. Bush [10, 13] for the technical creativity of inventors and researchers is the greatest. It is also called the questionnaire of the imaginary experiment of the inventor.

It contains, for example, the following questions:

1. How to solve the problem; if the costs are not taken into account, if a person's life depends on its solution, if the technical object will be used as a toy, or if the object is a teaching aid, an exhibit?

2. Can the solution principles rejected in the past be used now with modern technical capabilities?

3. Is it possible to predict the result of solving the problem in 10-15 years, taking into account the growth of social needs?

4. What does the list of all the main disadvantages of known solutions to the problem look like? What should be the resolution if they are eliminated?

Lists of control questions are developed by analyzing and summarizing the work experience of the company's technologists.

A list is a way of transferring experience, it allows you not to miss any important moments, to pay attention to something, it guides and expands the possibilities of finding a solution.

The method of heuristic questions, also known as the method of "key questions", is advisable to use for collecting additional information in the conditions of a problem situation or organizing already available information in the very process of solving a creative problem.

In addition, heuristic questions serve as an additional incentive, form a new strategy and tactics for solving a creative problem.

It is not by chance that in teaching practice they are also called "leading questions", because a question successfully posed by the teacher leads the student to the idea of a solution, the correct answer.

The method of heuristic questions is based on the following patterns and their corresponding principles:

difficulty and optimality (through artistically posed questions, the difficulty of the task is reduced to an optimal level);

breaking down information (heuristic questions make it possible to break down the task into subtasks);

goal assumption (each new heuristic question forms a new strategy - the goal of the activity).

The value of the method of heuristic questions lies in its simplicity and effectiveness for solving any problems.

Heuristic questions especially develop the intuition of thinking, the general logical scheme of solving creative problems.

The disadvantages and limitations of this method are that it does not provide particularly original ideas and solutions and, like other heuristic methods, does not guarantee absolute success in solving creative problems.

In the table 13.1 gives the basic rules of applying the method of heuristic questions.

Table 13.1 – Rules of the method of heuristic questions

For the manager	For students
A heuristic question should stimulate thought, not suggest an idea for solving a problem	Remember the most characteristic heuristic questions and, if possible, systematize them
Questions should contain minimal information	Ask yourself questions that: would simplify the task; would allow us to consider the problem from a new, unexpected point of view; would stimulate the use of acquired knowledge, experience in solving other problems; would allow breaking the task into subtasks; would encourage you to exercise self-control

Continuation of table 13.1

When setting a series of questions: gradually reduce the level of difficulty of the task; strive for their logical relationship; formulate them interestingly; stimulate both logical and intuitive thinking procedures; try that a new question would give a new, unexpected perspective on the problem; divide the task into subtasks, stages	-

Control questions and tasks for independent preparation

1. What is the essence of the method of control questions?
2. Does the abundance of control questions on the list mean that the answer to each of them must lead to a new idea?
3. In what form can the method of control questions be used?
4. If at least one interesting idea is obtained as a result of searching for a solution using the method of control questions, then can it be assumed that the questioner has completed his task?
5. Which of the researchers developed universal questionnaires?
6. What groups of control questions were created by A. Osborn?
7. What is the list of control questions compiled by T. Ailoart?
8. What is the essence of the list of control questions compiled by T. Ailoart?
9. What is the structure of the list of control questions according to T. Ailoart?
10. The solution of which creative problems is stimulated by the list of heuristic questions of V.I. Andreeva, compiled on the basis of D. Poya's recommendations?
11. Who created the largest inventor's imaginary experiment questionnaire?
12. What groups of questions are in the list of universal questions for the technical creativity of inventors and researchers, created by G.Ya. Bush?
13. On what regularities and corresponding principles is the method of heuristic questions based?
14. What are the basic rules of applying the method of heuristic questions?

15. Applying the rules of the method of heuristic questions from the table. 13.1, solve the scientific and technical problem of ensuring the stability of indicators of the braking efficiency of passenger cars during operation.

LECTURE OUTLINE 14

PLAN

14. Heuristic methods of finding ideas and solving scientific and technical problems. Methods of "bouquet of problems", inversions, synectics and empathies.

14.1. Methods of "bouquet of problems" and inversions

14.2 The method of synectics and empathy

Control questions and tasks for independent solution

14.1 Methods of "bouquet of problems" and inversions

The "bouquet of problems" method consists in the fact that, based on the initial formulation of the problem, several other problems are considered, thereby forming a group or "bouquet of problems".

The advantage of the "bouquet of problems" method is that it works well on tasks of any level and from any sphere of human activity.

An example of using the method when solving a problem: there are not enough vehicles on the route.

The solution of this problem includes the following stages [2].

1. The problem is formulated as it is: there are not enough vehicles on the route.

2. The general problem is formulated: 1st group: means of transportation.

We select generalized concepts:

means for transporting passengers;

means for long-term transportation of passengers;

means for long-term comfortable transportation of passengers;

items that allow passengers to be transported in a comfortable position;

means that allow transporting passengers at a fixed time;

2nd group: minibus. We summarize this concept:

limited space with a good microclimate;

a place to sit;

premises for accommodation of a large group of passengers;

a room in which the conditions for recording new information are created.

We write down generalized formulations:

there are no means of transporting passengers on the route (it turns out that you can use not only the minibus);

there are no items for long-term transportation of passengers on the route (it turns out that you can not only sit, but also stand).

3. Formulate the analogous problem:

where and how passengers are transported (on seats, standing);

how people who spend time in real estate sit: drivers, passengers, etc. (on folding chairs, etc.);

how animals, birds, fish maintain their body in a stationary state (they adopt special poses);

what you can sit on in the forest, in the field, in the desert, in the water, etc. (on a stump, grass, straw, etc.)?

4. We solve the problem at the level of physical interactions.

How to make it so that it is not necessary to just sit or sit still? For this you can:

equip all passengers with special receivers and organize video broadcasting of entertainment programs;

to issue the rules of passenger transportation to all passengers, and instead of addressing through a microphone, hold consultations (the number of attendees will decrease sharply);

equip minibuses with folding tables instead of seats (lengthen the legs of the chairs so that it is possible to ride standing).

5. Reverse problem:

how to make sure that no one sits in the minibus (declare transportation more expensive for those sitting);

how to make sure that people do not sit on the seats (do not let extra people in);

how to make it so that there are not enough seats for the same number of passengers (to make transportation very boring - a joke).

The inversion method. The inversion method is one of the heuristic methods of educational and creative activity, focused on finding ideas for solving creative problems in new, unexpected directions, often contrary to traditional views and beliefs dictated by formal logic and common sense.

The method of inversions is based on regularity and, accordingly, the principle of dualism, dialectical unity and optimal use of opposite (direct and reverse) procedures of creative thinking (analysis and synthesis, divergent and convergent thinking).

It is also based on the spread of a dialectical approach to the analysis of research objects (external and internal study, intensification and deceleration, unification and separation of system elements, etc.).

The undoubted advantage of the inversion method is that it allows developing the dialectic of students' thinking, finding a way out of a seemingly hopeless situation, and finding original, sometimes quite unexpected solutions to creative problems of various levels of difficulty and complexity.

Its shortcomings and limitations are that it demands from students a fairly high level of creative abilities, basic knowledge, skills and experience in educational and creative activities.

Pedagogical difficulties in the selection and construction of creative tasks that would require the use of the inversion method are also noted.

In the table 14.1 gives the basic rules for applying the inversion method when working with students [2].

Table 14.1 – Rules of the inversion method

For the manager	For students
Encourage students to reformulate the problem several times in order to understand it deeply	Start solving the problem by reformulating it. Is it possible to formulate the inverse problem of the data?
More often, next to the straight line, put inverse problems in front of the students	Remember that inversion is the search for ideas in directions opposite to traditional views, beliefs, common sense and formal logic
Demand dialectics of analysis and reasoning from students	For any idea, look for a counter-idea

Continuation of table 14.1

Encourage students to use opposite procedures and tools in the process of solving creative problems:	In the process of solving creative problems, try to use the opposite procedures and tools:
analysis and synthesis, logical and intuitive, static and dynamic characteristics of the object of study, external and internal sides of the object, increase or, conversely, decrease in size, concrete and abstract, real and fantastic, separation and union, convergence (narrowing the field or search) and divergence (expanding the search field); if it is not possible to solve the problem from the beginning to the end, try to solve it from the end to the beginning; etc.	

14.2 The method of synectics and empathy

The creator of synectics is considered to be U. Gordon [14].

The goal of developing the method is to strive to increase the probability of success in setting and solving problems.

The synectics method received further development in the works of H. Bush.

Synectics - a method of finding new solutions - is similar to "brainstorming" and differs from it only in that the main task is reduced to the discussion of one or two options for a technical solution, but with a detailed consideration of them.

The group includes specialists of various professions.

The synectic group consists of carefully trained specialists of various professions who possess special methods of psychophysiological activation of the creative process.

For this reason, synectics is unlikely to find wide application when working with students.

However, it is possible to organize synectic groups of teachers to solve complex administrative or pedagogical problems.

This method is currently most widely used by industrial firms that invest significant funds in the training and content of synectic groups.

The key point of synectics, which distinguishes it from "brainstorming", is the approach to the decision process.

During the entire work process, synectors try to get closer to a solution, but do not put forward finished ideas, as happens during "brainstorming".

Integrity, in their opinion, opposes further changes.

On the other hand, non-rational information is the reason for the manifestation of metaphors, images, still vaguely outlined, shaky in memory.

Constant stimulation of the subconscious leads to the manifestation of intuition, to enlightenment. Thus, according to Gordon, the results of solving the problem are rational, the very process of finding a solution is largely irrational.

The synectic group must bring the decision to a level that allows for the practical implementation of the idea.

Moreover, synectors are obliged to participate in the work at all stages of the practical implementation of the proposed ideas in order to keep themselves in good shape.

Without going into practice, the thinking process is locked in abstractions, and they lead to even greater abstractions and uncertainty.

In the conditions of applying the synectics method, premature clear formulation of the problem (creative task) should be avoided, because it will hinder the further search for its solution.

It is expedient to start the discussion not with the task (problem) itself, but with the analysis of some general features that, as it were, introduce into the situation of setting the problem, repeatedly clarifying its content.

You should not stop when proposing an idea, even if it seems that an original idea has already been found and the problem has already been solved.

If the creative task is not solved, it is advisable to return to the analysis of the situation that gave rise to the problem, or to break it down into subproblems.

Synectic sessions are held by specially formed groups of 5-7 people who have undergone preliminary training.

Synectors learn to find new ideas by using four types of analogies: direct, personal, fantastic, and symbolic.

Direct analogy is widely used in the practice of invention and engineering, as well as synectors, when knowledge is transferred from one field to another, the interpretation of the new with the help of known concepts, etc.

Synectors in the chain of analogies not only look for similar elements of structures in other fields of technology, as inventors do, but go further, for example, in search of protection of structures.

Personal analogy (called empathy). Empathy - understanding the emotional state of another person in the form of sympathy.

The synector also identifies himself with the object he is trying to improve or recreate, and imagines what he would do if he were in that object's place.

The task of any inventor, and even more so a synector, is to enter the image and become, for example, a part of a machine, and "see" from its position, its point of view, what can be done to improve it.

When the method of empathy is used, then the feelings and emotions of the person himself are attributed to the object: the person identifies the purpose, functions, possibilities, pluses and minuses, for example, of a machine, mechanism, with his own.

Thus, the basis of the empathy method is the principle of replacing the researched object or process with another.

Taking into account these remarks, the empathy method is one of the heuristic methods of solving creative problems, which is based on the process of empathy, that is, identifying oneself with the object and the subject of creative activity, understanding the functions of the studied subject on the basis of "use" in the image of the invention, which is attributed personal feelings, emotions, abilities to see, hear, think, etc.

When applying the method of empathy, a person seems to merge with the object of research, and this requires a huge fantasy, imagination; emerging fantastic images and ideas lead to the removal of barriers of "common sense" and the search for original ideas.

A fantastic analogy has to do with wishing for what you want to happen.

Thinking about fantastic, unreal or supernatural processes stimulates the emergence of new ideas.

An example of using the empathy method is given in the table 14.2 [2].

Table 14.2 – Rules of the Empathy Method

For the manager	For students
Remember that the basis of the empathy method is the principle of personal analogy, that is, attributing to the object of research personal human properties and qualities	

Continuation of table 14.2

Tell the students what it means to "enter the image", "get used to the image"	When starting to solve a creative task, mentally imagine yourself in the place of the object or process being studied (the stage of entering the "image")
Explain to the students how to attribute to the object of research the ability to feel, listen, see, think, that is, to have human properties and qualities.	Try to mentally add to the object, process (or its individual parts) the ability to feel, listen, see, reason, that is, to have human properties and qualities
Illustrate to students with concrete examples how you personally apply the method of empathy (for example, to design a new version of a gear, you need to imagine yourself as a gear)	After entering the "image", reason, as it were, from the "person of the object" or some component of the problem, until a productive idea for its solution arises

The advantages of the empathy method are huge, truly inexhaustible possibilities for the development of fantasy, imagination and obtaining original solutions to creative problems.

Symbolic analogy uses metaphors and similes, equating the characteristics of one object with the characteristics of another.

An example of the use of a symbolic analogy taken from the book by G.Ya. Bush, given in the table. 14.3.

Table 14.3 – Rules of the method of symbolic analogy

Concept	Symbolic analogy
Ratchet mechanism	Reliable continuity
The nucleus of an atom	Energy continuity
Target	Focal aspiration
Solution	Balanced confusion

The method of symbolic analogy is more often used by journalists and writers to vividly and succinctly reflect the contradictory essence of the described phenomena or characters.

Critical selection and evaluation of ideas for solving a creative problem should be carried out in several stages.

At the first stage, a short analysis of each proposed idea is made, at the second stage, it is advisable to group these ideas, critically analyze them and select the most original ones.

The advantages of the synectics method include almost everything that is characteristic of the heuristic methods on the basis of which it was developed.

Its shortcomings and limitations include the following.

The method of synectics does not allow solving too special creative problems, but gives an opportunity to find mainly the most original ideas for a solution.

After using the method for more than 30-40 minutes, the productivity of generating new ideas gradually decreases, students are distracted a lot and even have fun.

This method is not taken seriously. In addition, the method of synectics requires a lot of time. But the most important thing is that this method often only allows you to get an idea of a solution to the problem.

As research has shown, the presentation of ideas and their subsequent selection largely depend on the teacher, his skill, tact, dexterity, and his ability to stimulate the creative imagination of students.

He must master the art of asking questions, giving hints, clarifications, clarifications, inserting remarks that would stimulate and inhibit the imagination of students, sometimes narrowing and then expanding the field of finding a solution to a creative problem.

The teacher must follow some rules, for example, those listed in the table. 14.4 [2]

Table 14.4 – Synectics method rules

For the manager	For students
Remember that the method of synectics is a complex heuristic method based on the method of "brainstorming", the use of various types of analogies (verbal, figurative, personal, i.e. empathy), inversion, free associations, etc. Therefore, the method of synectics is characterized by all the rules of these methods	

Continuation of table 14.4

It should be taken into account that among the educational groups that apply this method, the best results are achieved by groups of 5 to 15 people, whose members have different levels of abilities, professional interests and training	Make the most of your personal experience, professional knowledge and skills
Encourage students to reformulate the problem several times	Premature, hasty, clear formulation of tasks-problems hinders the search for solution ideas or gives trivial solutions
Do not let the students calm down with the appearance of the first successful idea, look for a better, more original one	In the process of presenting ideas, use different types of analogies (concrete and figurative, semantic, personal, i.e. empathy), more often use metaphors, inversion, elements of games, think aloud
When encouraging students to generate ideas, use the following questions more often: So what? How do you imagine it? What's new here? And when to do the opposite? And if we strengthen (weaken) this effect?	Analyze the research object from the most unexpected points of view: scientific and life, external and internal

Control questions and tasks for self-study

1. What is the "bouquet of problems" method?

2. Complete the statement: Based on the original problem statement, several other problems are considered, thereby forming a group that contains a number of subgroups formed by ….

3. What is the main advantage of the "bouquet of problems" method among other heuristic methods?

4. What are the stages of solving a problem using the "bouquet of problems" method?

5. On the example of using the "bouquet of problems" method, solve the problem: determine the optimal route for vehicles during the transportation of passengers from the Saltiv massif "Northern 5" to "Khnadu".

6. Complete the statement: The inversion method is one of the heuristic methods of educational and creative activity, focused on finding ideas for solving creative problems...

7. What regularity and, accordingly, principles is the inversion method based on?

7. What is the advantage of the inversion method?

9. State the disadvantages and limitations of the inversion method.

10. Name the rules for applying the inversion method.

11. Who is considered the creator of synectics?

12. What is the purpose of using the synectics method?

13. What are the similarities and differences between the synectics method and the "brainstorming" method?

14. Is the statement true: The synectic group consists of carefully trained specialists of various professions who possess special methods of psychophysiological activation of the creative process?

15. Why, according to U. Gordon, are the results of solving a problem by the synectics method rational, and the process of finding a solution is largely irrational?

16. Why should premature clear formulation of the problem (creative task) be avoided when applying the synectics method?

17. Why, when applying the method of synectics, is it advisable to start the discussion not with the task (problem) itself, but with the analysis of some general features that, as it were, introduce the situation of posing the problem, repeatedly clarifying its content?

18. Why, when applying the synectics method, one should not stop when proposing an idea, even if it seems that an original idea has already been found and the problem has already been solved?

19. Complete the thought: If the creative task is not solved, then when applying the synectics method, it is advisable ...

20. By using what types of analogies do synectors learn to find new ideas?

21. In what case are direct analogies used by synectors in inventive and engineering practice?

22. What is the characteristic feature of the work of synectors?

23. What is a personal analogy called?

24. Is the statement true: Empathy is understanding the emotional state of another person in the form of empathy?

25. Name the rules for applying the empathy method.

26. What can be attributed to the shortcomings and limitations of the synectics method?

27. Name the rules for applying the synectics method.

LECTURE OUTLINE 15

PLAN

15.1 Objects of scientific and technical creativity

Every type of human activity, including creative and inventive activity, is determined by his desire to satisfy one or another material and spiritual needs.

Among them, first of all, are the needs related to improving the quality of human life: the creation of new and higher-quality products, goods and food products, clothing and shoes, more comfortable and safe working conditions, improving the ecology of the environment, etc.

This should also include human needs for preserving or restoring health, improving education, developing arts and crafts, improving communication links between people (transportation, communication, radio, television), etc.

A big role in the motivation and initiation of creative and inventive activity is played by a person's need to use his abilities and talent to do something useful for other people and society, thereby feeling the fulfillment and meaning of his life.

In other words, the objects of scientific and technical creative and inventive activity of a person can be any technical devices, from the simplest to the most complex, in any fields of technology, medicine, communication, transport, agriculture, space, sports, communal and home economics and other innumerable spheres of application of the human mind.

Types and forms of scientific presentation of research materials are described in the discipline "Technology of Scientific Research".

Any result of mental creative work is intellectual property.

Intellectual property is divided into four groups:

industrial property, which includes intangible objects of technical creativity, related to technology and production, protected on the basis of patent law;

achievements of science and art, protected on the basis of copyright;

typology of integrated microcircuits;

"know-how".

Since the book is devoted to the methodology, ways and means of creating industrial property, this section will consider only the protection of industrial property objects.

However, it will also be interesting for readers to familiarize themselves with other groups of intellectual property.

The objects of copyright are artistic and scientific literature, musical and choreographic works, cinema and video films, works of painting and sculpture, architecture, etc.

This group of copyright objects also includes computer programs, course and diploma projects of students, creative projects and competitive works of students.

To protect the author's rights, each copy of his work contains a copyright protection sign consisting of three elements: the Latin letter "C" inside a circle - ©, the name of the author or the name of the copyright holder, and the year of first publication.

Computer programs and typologies of integrated microcircuits are registered in the Ukrainian Agency for Legal Protection of Computer Programs, Databases and Typologies of Integrated Microcircuits, which issues them with appropriate certificates.

"Know-how" means official and commercial secrets.

"Know-how" is a set of various scientific, technical, production, administrative, financial or other knowledge, experience, practically applied in the activity of an enterprise or professional activity, but which have not yet become common property.

Objects of "know-how" can be economic information; experience in conducting commercial operations; knowledge of the market situation;

management structures, production management methods and schemes; technical objects unprotected as objects of industrial property, or unprotected objects of copyright.

Industrial property is intangible objects of technical creativity. This group of objects includes:

inventions;

useful models;

industrial samples;

trademarks;

names of places of origin of the object.

The objects of patent law include only the first three types of objects: inventions, utility models, and industrial designs.

Patent law is a set of norms that define and regulate non-property and property relations that arise in connection with the creation and use of objects of industrial property.

Patent law norms are established by the Patent Law of Ukraine.

It is possible to determine to which type this or that object belongs by analyzing its essential features and comparing them with typical features of the types of objects of inventions.

Such a feature that determines the content of the structure and composition of the object is considered significant.

In order to determine whether this or that feature is significant, it is conditionally excluded from the object.

If at the same time the object becomes inoperable or its efficiency deteriorates sharply, this means that the feature in question is significant.

The devices are characterized by the following typical features:

the presence of nodes, details, elements;

interconnection of nodes, parts and elements;

the shape and mutual arrangement of parts, nodes and elements;

dimensions, weight and other parameters of nodes, details, elements;

materials from which they are made.

Methods are processes of performing specified actions on material objects using other material objects.

The methods are characterized by the following typical features:

the presence of actions;

sequence of actions;

conditions and modes of performance of actions;

materials and devices used in performing actions.

Since during the implementation of methods all actions are performed by people (operators), then in the formulations of the signs of the method of action, verbs in the real (present) state of the real mode must be expressed, and in the 3rd person plural (for example: drill, cut, collect, etc.).

Typical features of the substance are:

composition and quantitative ratios of components;

the shape of components, their structure and dimensions;

the physical state of the substance or its individual components.

Since the substance is characterized by signs as a product ready for use, in the wording of its signs, it is worth using verb forms that show this state of the substance (for example, contains, consists of, introduced, etc.).

The author of the invention is a person (according to legal terminology – a natural person), whose creative work it was created.

If the object of industrial property was created jointly by several persons, then all of them are considered equal authors.

In this case, the procedure for using authors' rights is determined by an agreement between them.

The right to an invention and an industrial design is certified by a patent, and to a utility model and trademark by a certificate.

These official protection documents are issued by the patent office. A patent is a document certifying:

copyright;

the priority established from the date of receipt of the author's application by the patent institution;

exclusive right of the author to use the invention or industrial design.

15.2 Criteria for assessing the level of solving scientific and technical problems

When solving inventive problems, heuristic methods of finding new ideas and the best design and technological solutions are mainly used.

The highest results of scientific and technical creativity are discoveries, inventions and useful models.

The number of discoveries and inventions and their economic effect are the most important criteria of scientific progress, the main form of development and creation of new equipment and technology.

Discoveries form the basis of the scientific and technological revolution. They determine the essence of fundamentally new directions of development of science and technology and exert a revolutionary influence on social material production.

Technical solutions to purely scientific problems, solving problems in any technical field and other spheres of social activity, aimed at meeting public needs, are classified as inventions.

Invention is a creative process that leads to a new solution to a problem in any field of technology, culture, health care, defense, and the positive effect it gives.

In the broadest sense of the word, an invention is a new technical solution to a problem that increases the existing level of technology.

An inventive task is one that contains a technical contradiction that cannot be resolved by known technical means and knowledge, and the conditions of the task exclude a compromise solution.

If the technical contradiction is overcome, then the inventive problem is solved.

Technicality, novelty, significant differences, positive effect as a criterion for the protectionability of inventions are not related to the problem, but to its solution, although similar characteristics of the problem may indirectly affect the characteristics of the solution.

An achievement that can be defined as an invention is called defensible according to a number of criteria: task, solution, technical nature of the solution, novelty, significant differences, positive effect.

Application for an invention. The invention must be discovered on time and correctly.

An application is made for any invention.

The source of discovery of inventions is the use of scientific research or research and development works, the study of the existing state of technology, the development of a technical task, the manuscript of articles and books.

The objects of inventions are devices, methods, substances, strains of microorganisms, cell cultures, plants and animals, applications known in a new way.

The object of scientific and technical creativity is most often devices and methods, less often – substances.

The presence of a problem in the definition of the invention implies a positive effect.

A task is a set goal, and a positive effect is the possibility of achieving the goal as a result of using the invention.

According to the "availability of a task" criterion, all proposals are divided into three categories:

proposals containing socially important tasks, the solution of which assumes a positive effect;

proposals that do not contain socially important tasks. Solving them cannot be effective. They cannot be recognized as an invention;

proposals containing anti-social problems, the solution of which gives a negative result.

The solution of the problem should not be cognitive, but utilitarian in nature, should be related to the satisfaction of practical needs.

In this regard, scientific provisions, including discoveries, are not recognized as inventions.

Unrealized, false proposals are also not recognized as inventions.

Solving a problem is one of the most important properties that, from a subjective point of view, is the result of a person's creative activity.

Creativity is not included among the normative criteria of invention, because it is contained in the criteria of "solution" and "novelty" and is their result.

Achieving a positive effect is the main sign of solving the problem.

The problem is considered solved when the solution meets three conditions:

the proposal has requirements for technical solutions;

the decision reveals fundamentally important points;

the solution is implemented, that is, it is suitable for use.

There are various cases of the lack of a solution to the problem in an application for an invention.

In general, they are divided into four groups:

setting a problem (without solving it);

solution error;

incompleteness of the actual solution;

non-disclosure of the solution in the description or claims.

First of all, invalid (unfeasible) proposals belong to erroneous decisions.

Sometimes the impossibility of the solution in the proposal is not so obvious and requires a detailed check.

A solution that improves some work qualities, but worsens others, cannot be recognized as an invention.

Novelty. The invention must be new. This criterion indicates the presence of creativity.

In the invention law, novelty involves only taking into account its presence or absence, without assessing the degree of creativity.

During examination of an application for an invention, a decision is recognized as new if, before the date of receipt of the application, the essence of this or a similar decision was not disclosed in Ukraine or abroad to a certain circle of persons to the extent that it became possible to implement it.

The priority of the invention is established on the day the application is received by the State Committee.

Moreover, the level of existing technology means the totality of any technical information that has become publicly available in the world at the time of filing the application.

The inventive level of a technical solution takes place if the components of its new features clearly do not follow from the level of existing world technology.

An invention is recognized not just any, but only a technical solution characterized by an important independent criterion of security.

A difference that has a mechanical, physical, chemical, biological and cybernetic nature is considered technical.

The industrial applicability of a technical solution is considered proven if it can be implemented or used in industry, transport, medicine, agriculture and other areas of human life, firstly, with the help of means known in technology and, secondly, provides that or another technical effect.

The positive effect of the invention is a new, higher result that society will get when using the invention compared to the result obtained from the prototype object or other compared solutions.

The absence of higher results under any conditions is a sign of the absence of a positive effect. But inventions include solutions that cannot be used immediately in the planned conditions or whose positive effect is possible in the future when conditions that are not currently available are reached.

A positive effect can represent both a direct and an indirect result of a decision.

Significant differences depend on the development of technology.

According to the "Patent Law of Ukraine", technical solutions that have novelty and industrial utility, but do not have an inventive level, are subject to legal protection as utility models.

Useful models (they are sometimes called "small inventions") are basically constructive devices from the field of mechanics, means of production, and consumer goods.

The author of a new technical solution, at his discretion, can register the object created by him (which meets all the requirements of all three criteria for the identification of inventions) as an invention or as a utility model.

The difference between an invention and a utility model is mainly legal, but the procedure for issuing a certificate for a utility model is much simpler and faster than for issuing a patent for an invention.

Many authors are also attracted by the fact that a lower fee is charged for registering a utility model than for obtaining a patent.

The formula of the invention is a short verbal description compiled according to the established rules, which reflects the technical essence of the invention with the features of the object of the invention (machine, assembly, part, operation, mode parameter, etc.).

The formula of the invention for use characterizes the use of known devices, means and substances for a new purpose. It expresses the technical essence of three types of inventions:

in relation to objects, one of which is intended for obtaining, implementing or using another object;

alternative solutions containing claims that cannot be covered in one clause;

which refer to the whole object and its parts.

The description of the invention has a target purpose and is both informational and legal in nature. The description must meet the following requirements:

fully disclose the technical essence of the invention in an amount sufficient for further development and use;

to give an accurate and clear idea of the novelty;

to give significant and positive effects of the technical solution;

to have distinctive features of the contribution from the introduction of the invention to this branch of the national economy.

The description of the invention is carried out in the form of separate paragraphs without headings in the following structure:

1) name of the invention and section of the IPC;

2) the field of technology to which the invention belongs and the predominant field of its use;

3) characteristics of analogues of the invention;
4) characteristics of prototypes;
5) criticism of the prototype;
6) essence of the invention;
7) a list of figures, graphic images (if necessary);
8) examples of specific implementation of the invention;
9) technical and economic or other efficiency;
10) formula of the invention.

15.3 The invention. The right to obtain a patent and basic requirements for filing an application

An invention is the result of a person's creative activity in any field of technology.

The right to an invention is protected by the state and certified by a patent.

An invention patent is a legal and technical document that certifies: ownership of an invention; priority; the authorship of the creator of the invention and the exclusive right of the patent owner to use the protected object.

A Ukrainian patent for an invention is valid only on the territory of Ukraine.

The term of validity of a patent for an invention is 20 years from the date of submission of the application to the State Patent Office of Ukraine (hereinafter referred to as the Office), subject to the payment of a fee for maintaining its validity.

The object of the invention can be any solution to the problem claimed as an invention:

product (device, substance, microorganism strain, plant and animal cell culture);

way. Device - machines, mechanisms, devices, parts, assemblies or a set of interconnected parts and assemblies.

A strain is a hereditarily homogeneous culture of microorganisms that produce useful substances or are used directly.

The method is the process of performing actions on a material object (objects) with the help of material objects.

The law defines which results of human activity are not recognized as inventions. They include:

discoveries, scientific theories and mathematical methods;
methods of organization and management of the economy;
plans, notations, schedules, rules;
methods of performing mental operations;
programs for computing machines;
results of artistic construction;
topography of integrated circuits;
species of plants and species of animals, etc.

Patentability is a property acquired by an object of economic activity (product or method) in case of compliance with the conditions for granting legal protection of an invention in accordance with the Law.

The law defines three main requirements that a patentable invention must meet:

to be new;
have an inventive level;
be industrially suitable.

An invention is recognized as new if it is not part of the state of the art, which includes all information that has become publicly available in the world before the date of filing the application with the Office or before the date of its priority, if the applicant exercises the right to priority of a previous application for the same invention.

The law establishes the principle of world novelty.

"Publicly available" should be understood as information whose distribution is not limited, for example, by the label "secret", etc. It should be borne in mind that novelty can be discredited by all applications submitted to the Office under the condition of earlier priority, despite the fact that these documents cannot be classified as publicly available.

An invention has an inventive level if, for a specialist, it does not follow from the state of the art, i.e. no solutions have been found that have features that coincide with the distinguishing features of the claimed invention, or if such solutions have been discovered, but the knowledge of the influence of the distinguishing features of the claimed invention on the technical result has not been confirmed , specified by the applicant in the application.

Any invention can be characterized by some set of essential features, each of which is necessary, and all together are sufficient to achieve the technical result that the invention provides.

Industrial applicability is the possibility of using the invention in industry, agriculture or other areas of human activity.

The main meaning of the requirement "industrial suitability" lies in the possibility of implementing the proposed solution in the form of a specific material means of production.

The right to receive a patent. An application for the issuance of a patent may be submitted by the inventor or his heir, employer or legal successor of the inventor or employer (hereinafter referred to as the applicant).

An intellectual property representative (hereinafter referred to as a patent attorney) or another authorized person may submit an application on behalf of the applicant.

An inventor is a natural person whose creative work created an invention.

The law clearly separates the inventor from other persons who provided him only with technical, organizational, material and legal assistance or assistance in conducting research work and producing technical documentation.

If several natural persons participated in the creation of the invention, all of them are recognized as inventors, and the procedure for using the rights belonging to them is determined by an agreement between them.

Copyright is a personal non-property right and belongs to the inventor. It is inalienable: it is not transferred to other persons and it is protected: indefinitely, it does not pass to the successor, unlike the property rights certified by a patent.

A legal entity cannot be defined as an author.

"Official invention" means an invention created on behalf of the employer or in connection with the performance of official duties by the inventor.

If an application for an invention is submitted by an employer, he has the right to receive a patent, provided that the employment contract (contract) between the inventor and the employer does not provide otherwise.

The employer can exercise the right to submit an application only within four months from the date of receipt of a written notification from the inventor about the created invention.

If the employer does not submit an application to the Office within the term specified by the Law, the right to obtain a patent passes to the inventor.

The contract concluded between the inventor and the employer can be typical (the same, for example, for the entire engineering staff) or individual - for individual inventors who have a high creative potential.

Basic requirements for filing an invention application.

An application for an invention is a set of documents required for the issuance of a patent.

The application must relate to one or a group of inventions connected by a single inventive concept (unity of invention requirement).

The application must contain:

an application for the issuance of a patent for an invention;

description of the invention;

the formula of the invention;

drawings or other materials, if they are needed to understand the essence of the invention;

abstract, which is an abbreviated summary of the content of the description of the invention.

All the above materials are prepared and submitted in triplicate. The application is submitted according to the established form.

The application should include the full name or title (for a legal entity) of the applicant(s) and their address(es), as well as information about the inventor(s).

Rules for the description and design of the invention are given in [1-6].

15.4 Useful model. Patentability, conditions for granting legal protection and basic requirements for filing an application

A useful model is the result of human creative activity in any field of technology.

The right to a utility model is protected by the state and certified by a patent.

All issues related to the acquisition and use of ownership rights to utility models in Ukraine are regulated by the Law of Ukraine "On the Protection of Rights to Inventions and Utility Models" dated December 15, 1993 No. 3687-XII (hereinafter - the Law).

A patent for a utility model is a protective document issued on behalf of the state by an authorized state body.

A patent certifies: ownership of a utility model; the priority of the useful model; authorship of the creator of the utility model; the exclusive right of the patent owner to use the protected object.

The term of validity of a patent of Ukraine for a utility model is five years from the date of submission of the application to the State Patent Office of Ukraine (hereinafter - the Office), subject to the payment of a fee for maintaining its validity, and may be extended at the request of the patent owner, but for no more than three years .

The validity of the Ukrainian utility model patent extends only to the territory of Ukraine.

In order to obtain a patent of Ukraine for a utility model (if there is a right to this), it is necessary to submit an application to the Scientific and Research Center for Patent Examination (hereinafter - NDCPE), which is an expert body of the Office, drawn up in accordance with the Rules for drawing up and submitting an application for the issuance of a patent of Ukraine for an invention (utility model) dated December 27, 1994 No. 318/528 (hereinafter - the Rules).

Conditions for granting legal protection of a utility model.

Legal protection is provided to a useful model that does not contradict public interests, the principles of humanity and morality and meets the conditions of patentability.

A useful model is called a "small invention", that is, it is an invention that is new, but has a low creative level.

The object of a useful model can be a constructive implementation of the device.

The protection of utility models aims to speed up and reduce the cost of the mechanism of protection of constructive developments in comparison with inventions.

A simpler protection mechanism is due to sufficiently fast updating of the consumer market in conditions of competition.

Solutions related to methods, substances, strains of microorganisms, plant and animal cell cultures are not protected as a useful model according to the Law.

In addition, projects and planning schemes of buildings and territories are not recognized as useful models; proposals regarding the appearance of the product aimed at satisfying aesthetic needs, as well as other objects that do not fall under the concept of "constructive performance of the device" at all.

Patentability of a utility model.

For a solution to be recognized as a useful model, it must be new and industrially applicable.

A utility model, like an invention, is a technical solution to a problem.

Legal protection is not granted to any technical solution, but only to that which concerns devices, namely: the constructive execution of the means of production and consumer goods.

A useful model is not subject to inventive step requirements, but this does not mean that a useful model can be any solution recognized as obvious to a specialist.

A useful model should be the result of independent inventive creativity.

A utility model is considered new if it is not part of the prior art, which includes all information publicly available in the world before the date of filing the application with the Office or before its priority date, if the applicant exercises the right of priority of a previous application for the same utility model.

The law establishes the principle of world novelty.

"Publicly available" should be understood as information whose distribution is not limited, for example, by the label "secret", etc.

It should be borne in mind that novelty can be discredited by all applications submitted to the Office under the condition of earlier priority, despite the fact that these documents cannot be classified as publicly available.

A utility model is considered new if the set of its essential features is unknown from the prior art.

All signs that affect the expected result are considered essential.

Disclosure of the essence of the utility model in a publicly available source of information by the inventor, the applicant or a person who received relevant information from them directly or indirectly within 12 months before the date of filing the application with the Office (before the priority date) does not affect the recognition of the utility model as new.

In the event of a dispute, the applicant must prove this fact.

Industrial suitability is the possibility of using a useful model in industry, agriculture or other areas of human activity.

The main meaning of the requirement "industrial suitability" lies in the possibility of implementing the proposed solution in the form of a specific material means of production or an item of consumption.

The right to obtain a utility model patent.

An application for the issuance of a patent for a utility model may be submitted by the inventor or his heir, employer or legal successor of the inventor or employer (hereinafter referred to as the applicant).

On behalf of the specified persons, the application can be submitted through an intellectual property representative (hereinafter - a patent attorney) or another authorized person.

Foreigners and other persons living or having a permanent place of residence outside Ukraine exercise their rights in relations with the Office through patent attorneys.

An inventor is an individual whose creative work has created a useful model.

The law clearly separates the inventor from other persons who provided him only with technical, organizational, material and legal assistance or assistance in conducting research work and producing technical documentation.

If several natural persons participated in the creation of a utility model, all of them are recognized as inventors, and the procedure for using the rights belonging to them is determined by an agreement between them.

Copyright belongs to the inventor and is his personal non-property right. It is inalienable: it is not transferred to other persons and is protected indefinitely, it does not pass to the successor, unlike property rights certified by a patent.

Authorship of legal entities is not recognized.

The right of the employer. If the utility model was created on behalf of the employer or in connection with the performance of official duties by the inventor and the application is submitted by the employer, he has the right to receive a patent, provided that the contract between the inventor and the employer does not provide otherwise.

The employer can exercise the right to submit an application only within four months from the date of receipt of written notice from the inventor about the creation of a utility model.

If the employer has not submitted an application to the Office within the term specified by the Law, the right to obtain a patent passes to the inventor.

The contract concluded between the inventor and the employer can be typical (the same, for example, for the entire engineering staff) or individual (for individual inventors with high creative potential).

Basic requirements for filing an application for a utility model.

An application for a utility model is a set of documents required for the issuance of a patent.

The application must relate to one utility model (unity of utility model requirement).

The application must contain:

an application for the issuance of a patent of Ukraine for a utility model in the established form;

description of the utility model;

the formula of the useful model;

drawings or other materials, if they are needed to understand the essence of the useful model;

abstract, which is an abbreviated summary of the content of the description of the utility model.

All the above materials are prepared and submitted in triplicate.

The application is submitted according to the established form.

In the application, it is necessary to indicate the full name or title (for a legal entity) of the applicant(s) and his/her address, as well as provide information about the inventor(s).

The application is signed by the applicant and the date of signature is affixed.

If the applicant is a legal entity, the application is signed by the manager (or a person authorized to do so) indicating his position, surname, initials, and the signature is certified with a seal.

If the applicant has entrusted the handling of the application to a patent attorney or other authorized person, the latter may put his signature instead of the applicant, and the power of attorney issued by the applicant is attached to the application.

The description of the utility model must be so clear and complete with all technical details and confirm the scope of legal protection defined by the formula of the utility model that a person skilled in the relevant field can implement it.

Control questions and tasks for self-study

1. What are the objects of scientific and technical creativity?
2. What are the criteria for assessing the level of solving scientific and technical problems?
3. What is a discovery?
4. What are the characteristics of the invention?
5. Define the concept of "positive effect of the invention".
6. In what cases is the inventive task considered solved?
7. Give the sequence of the description of the invention. What requirements should the description meet?
8. What are the rights to obtain a patent and what are the main requirements for filing an application for an invention?
9. How does an invention differ from a utility model?
10. What is utility model patentability?
11. What are the rights to obtain a utility model patent?
12. What are the main requirements for filing an application for a utility model?
13. What are the main functions of a sign for goods and services?
14. What are the conditions for granting legal protection of a mark?
15. What is the essence of marks for goods and services and their legal protection...

LECTURE OUTLINE 16

PLAN

16.1 Concept of model and modeling. Types of models and requirements for their construction

In order to most fully understand this or that process, it is necessary to conduct a sufficiently large number of observations and measurements that allow formulating some database.

At the next stage, it is necessary to highlight the main thing and only then conduct scientific studies of some processes or phenomena, using the information formulated and systematized at the first stage.

Systematization of data allows you to "condense them" into such an abstract concept as "model".

A model is understood as an artificial object (system) of any physical nature that reflects the main properties of the studied object - the original.

In the process of cognition, a person always, more or less explicitly and consciously, builds models of situations in the surrounding world and directs his behavior in accordance with the conclusions obtained by studying the model.

A model is an image in a convenient form of numerous information about the object under study.

It is in a certain correspondence with the studied object, can replace it during the study and allows you to receive information about the studied object.

A model - physical, abstract, logical, mathematical-analytical, simulation, experimental, mathematical-machine with the involvement of electronic models and computers, tabular, vector, graphic or in another form - is always in one way or another simpler, more accessible than the original.

Studying the model as a more accessible object provides new knowledge about the original.

It should allow conducting an experiment not on a real-life object (model), not on a real physical model of the object under study, but according to its description.

The model should reflect only some features and properties of the original object, essential for obtaining answers to questions that will interest the researcher.

Many models can be made from the same original, reflecting certain qualities of the original.

The model allows you to study the properties of the original object (process, phenomenon), when the study of nature is impossible, inconvenient, expensive, dangerous, long-term, etc.

When building a model, the object and its properties are mentally generalized and simplified.

The model is performed with optimal complexity based on the research goal.

All models can be classified according to two features:

1) construction method;

2) qualitative specificity of the process or object being modeled.

Real (live, analog) models are objects that exist in reality and are created from real materials.

Such models assume, as a rule, a real reproduction of the object under study and can be geometrically similar to it (for example, reduced copies), physically similar (physical processes studied, their kinetics and dynamics, various types of connections are reproduced) or mathematically similar (for example, analog models built on the basis of electromagnetic and electroacoustic analogies).

For example, when designing a new car, its layout is created, which has the same aerodynamic properties; when planning a building, architects make a layout that reflects the spatial location of its elements.

In this regard, full-scale modeling is also called mock-up.

Material models are inextricably linked with ideal ones, because a person, before building a model from any materials, mentally imagines the future material model.

Ideal (symbolic) models are abstract descriptions of this or that object or phenomenon of the real world that allow analyzing its properties.

The advantages of ideal models are that they allow relatively simple and inexpensive means to analyze the behavior of technical and environmental systems and to predict the nature of their changes when certain changes are made to the system.

Ideal (symbolic) models have more opportunities than real ones, because they are almost not bound by the technical limitations of their creation.

In symbolic models, the property of visibility is absent, because the concept of "sign" excludes the similarity between it and the object or phenomenon that it denotes.

Due to its iconicity, such a model, by its physical nature, has nothing to do with the nature of the elements of the modeled objects.

Ideal models remain imaginary even when they are embodied in some material form, in the form of a drawing, drawing, scheme or simply a system of signs (mathematical formulas).

All transformations into them, all transitions to another state are carried out mentally, that is, in the consciousness of a person.

Without imaginary transformations, drawings, drawings, etc. lose their meaning.

Symbolic models are divided into conceptual and mathematical.

A mathematical model is a set of mathematical relationships that connect the initial characteristics of the state of a physical object with input information, initial data, restrictions imposed on the functioning of the object.

The mathematical model is in a certain correspondence with the physical object and is able to replace it with the goal that the study and research of the model gives new information about the behavior of the object (mechanism of processes, dynamics, behavior of the object both in the past and in future, etc.).

Mathematical models can be classified according to a number of features, according to which a mathematical apparatus is chosen, designed to serve as a language for describing the properties, structure and behavior of the original.

There are a priori and a posteriori models.

The first are derived on the basis of theoretical considerations, and the second - on the basis of empirical data.

The choice of a mathematical apparatus also depends on the composition of actual information.

Descriptions of the functioning of ecosystems are usually characterized by uneven study of individual processes. Often, not only the mathematical type of dependencies between individual components is not known, but also there are no quantitative characteristics of the processes at all.

Analytical modeling involves the use of a mathematical model of a real object in the form of algebraic, differential, integral and other equations that connect the output variables with the input variables and are supplemented by a system of constraints.

At the same time, it is assumed that there is a unique computational procedure for obtaining an exact solution of the equations.

Iconic models are constructed in the human mind from images of some real phenomena or objects (liquids, gases, vapors, flows, etc.).

In mixed models, the iconic model is complemented by a drawing, drawing, scheme, graph. This gives the iconic model the property of visibility.

According to the qualitative specificity of the process or object being modeled, the following types of models are distinguished: dynamic and static; continuous and discrete; deterministic, quasi-deterministic and probabilistic; complete and partial; conceptual; structural; functional; substantial; procedural, etc. (see Fig. 16.1).

Мірою ефективності проведення операції слугує показник ефективності.

У загальному випадку він відбиває результат проведення операції, що, у свою чергу, є функцією трьох факторів: корисного ефекту операції (q), витрат ресурсів на проведення операції (c) і витрат часу на її проведення (t).

The values of q, c and t depend on the strategy of operation (i).

In formal form, the above can be written as follows [1-6]

$$Y_{оп} = Y\{q(i), c(i), t(i)\}. \qquad (16.1)$$

It is obvious that real benefit from modeling can be obtained only if two conditions are met:

the model provides a correct (adequate) display of the properties of the original, which are essential from the point of view of the investigated operation;

the model allows you to eliminate the above-mentioned problems that exist during measurements on real objects.

Note that, like real systems, their models can be classified according to the type of system being modeled, the language used to describe the functioning of the system (logical, informational), the field of system research (economic, psychological, physiological, etc.), purpose (descriptive, normative) .

Descriptive models are intended to explain the observed factors or predict the behavior of an object. They answer the question "how is it happening, how will it develop?".

Normative - designed to determine the best or acceptable state of the object from the point of view of the researcher. They answer the question "how should it be?".

Modeling is the study of objects of knowledge based on their models, it is the process of building, studying and using models of real objects, processes, phenomena and constructed objects.

A model in a broad sense is an image of an original object. It reproduces the most characteristic features of the researched object, the choice of which is determined by the specific purpose of the research and is limited by the framework of the task.

It is clear that the model must be adequate (isomorphic, similar) to the original.

Modeling is one of the main categories of cognitive theory.

Actually, any method of scientific research is based on the idea of modeling, both theoretical and experimental (using subject models).

Modeling in specific sciences is carried out with the aim of clarifying the properties of an original object, process or phenomenon with the help of another (analogous, isomorphic, adequate) model object, between which certain quantitative relationships exist and are probably established.

Modeling is based on a rigorous theoretical base, which includes the theories of analogy and similarity.

Models built on the basis of analogies are called "analog models".

In the case of applying the similarity theory, the obtained models are called "similarity models".

The theory of similarity is based on three theorems.

Theorem 1. Two physical phenomena are similar if they are described by the same system of differential equations and have similar (boundary) conditions of uniqueness, and their determining criteria of similarity are numerically equal.

Theorem 2. If physical processes are similar, then the criteria of similarity of these processes are equal to each other.

Theorem 3. Equations that describe physical processes can be expressed by the differential relation between similarity criteria.

Example 1. In the most general form, the similarity of the rolling conditions of the wheels on the road and on the stand with running drums can be characterized on the basis of the principle of similarity of elastic systems.

At the same time, the similarity coefficient K_p is determined by the expression

$$К_p = \frac{P}{E \cdot F^2},$$

wehere P – active load;

E – modulus of elasticity;

F – linear size (contact area).

When identifying the value of the module E, the ratio will be marked, that is, the specific load

$$p_п = \frac{P}{F^2}.$$

Example 2. Empirical comparative evaluation established that the rolling losses on the stand with the ratio (k_k) of the drum radius (r_b) to the wheel radius (r_k) are similar to the rolling losses in road conditions

$$k_k = \frac{r_b}{r_k} = 0{,}6 - 1{,}0.$$

Similarity criteria of any phenomenon can be transformed into criteria of a different form by means of operations of multiplication or division of previously found criteria by each other.

All types of relationships of similarity and modeling can be classified as: complete, incomplete, approximate modeling.

All types of modeling can be either deterministic, reflecting a process with clearly defined causes and their consequences, or stochastic, reflecting probabilistic events.

Modeling of any kind can be carried out both in real time and in modified time.

Spatially similar models are created in the form of layouts.

Physically similar models are built to study the dynamics of processes, the identity of the laws of their movement.

In physical modeling, the physics of phenomena in the object and model and their mathematical dependencies are the same.

In mathematical modeling, the physics of the phenomena can be different, but the mathematical dependencies are the same.

Mathematical modeling acquires mathematical value when there is a need to study particularly complex processes.

Mathematically similar models do not require mathematical and geometric similarity, the main thing is analogy.

Physical models allow you to visually depict the processes occurring in nature.

With the help of physical models, it is possible to study the influence of individual parameters on physical processes.

Mathematical models make it possible to quantitatively study phenomena that are difficult to study using physical models.

Live models are large-scale changeable objects that allow the most complete study of the processes taking place in live studies.

There are no standard recommendations for choosing and building models. The model should reflect essential phenomena and processes.

Small factors, excessive detailing, secondary phenomena only complicate the model, complicate theoretical studies, make them cumbersome, unfocused.

Therefore, the model should be optimal in terms of its complexity, preferably visual, but most importantly, sufficiently adequate.

In order to build the best model, it is necessary to have deep and comprehensive knowledge not only of the topic, related sciences, but also to know well the practical aspects of the researched problem.

It is possible to study and analyze the object most fully only if its model is presented as a description of a physical entity and has a mathematical form.

Mathematical models can be analytical dependencies or graphs, differential equations describing the movement of systems, tables or graphs of system transitions from one state to another, etc.

Analog modeling is based on the isomorphism of phenomena that have a different physical nature, but are described by the same mathematical equations.

Analogue models are similar to the original only in some functional properties.

With the help of these models, it is possible to statically and dynamically reproduce the properties of technical systems. For example, with the help of electronic computers, dynamic processes in systems of various physical nature are simulated, which are described by the same differential equations as processes in computers.

Another example can be the study of a hydrodynamic process using the study of an electric field.

Both of these phenomena are described by Laplace's differential equation in partial derivatives, which can be solved by conventional methods only for certain cases.

At the same time, experimental studies of the electric field are much simpler than the corresponding studies in hydrodynamics.

Iconic models reproduce the original in two- or three-dimensional dimensions, as necessary in a reduced or enlarged scale, for example, drawings, three-dimensional models of machines and machines, photographs. At the same time, the external similarity between the model and the original is great.

16.2 Building a conceptual model

A conceptual (content) model is an abstract model that defines the structure of the modeled system, the properties of its elements, and the cause-and-effect relationships inherent in the system and essential for achieving the goal of modeling.

In fact, it is a formalized description of the studied system, which consists of text, a block diagram, tables, graphs, and other illustrative material.

The construction of a conceptual model includes the following stages [10-13]:

determination of system type;

workload description;

decomposition of the system.

At the first stage, actual data is collected (on the basis of work with literature and technical documentation, field experiments, gathering expert information, etc.), as well as putting forward hypotheses regarding the values of parameters and variables for which there is no possibility of obtaining actual data.

If the obtained results correspond to the principles of information sufficiency and feasibility, they can be the basis for assigning the modeled system to one of the known types (classes).

16.3 Scheme of building a mathematical model

A mathematical model is the final product of the process of abstraction, formalization of the phenomenon under study; it is a system of relationships: formulas, functions, equations, systems of equations that describe certain aspects of the object, phenomenon, or process being studied.

Mathematical models make it possible to quantitatively study processes or phenomena that are difficult to study with the help of physical models.

When building a model, the properties and the object itself are usually simplified and generalized, which allows to study it with the disconnection of non-essential connections, to implement those conditions that are unattainable in practice.

The closer the model is to the original, the more successfully it is described, the more effective the theoretical research and the closer the obtained results are to the accepted research hypothesis and prediction of the state of the object.

Mathematically similar models do not require the fulfillment of the conditions of physical and geometric similarity.

Here, the relationship between the model and the real object is reduced to an analogy. This analogy can be structural or functional (isomorphism or isofunctionalism), which is reflected in the presence of the same mathematical formalism.

These models include all kinds of analog models (for example, electrical models of mechanical, thermal, acoustic phenomena, etc.), structural, digital and cybernetic functional models.

The first stage of developing a mathematical model is the construction of a strengthened, schematized image, a "figurative" model.

Such model-images are, for example, in mechanics, images of a material point, an absolutely solid body; in astronomy – the planetary system as a system of material points; in physics - the planetary model of the atom, etc.

A successful schematization of the object largely determines the success of the research and construction of the theory of the phenomenon.

Thus, the image of the solar system in the form of a system of material points having a defined mass, which is characterized by the force of gravity, made it possible to calculate the movement of the planets with high accuracy.

The next stage is the mathematization of the image model, the establishment of the necessary set of parameters and characteristics, and the determined relationships between them.

Here, of course, some fundamental laws of nature are used, others are previously established regularities that limit the possible values of the object's parameters.

As a result of the carried out mathematization, what is commonly called a mathematical model will be formed.

Various transformations and experiments can be performed with the formal model (simplify the structure of the model, apply substitution schemes, etc.).

Mathematical models, numerical methods and computers made it possible to design complex technical systems and obtain characteristics close to those calculated.

A mathematical model should be as simple as possible in handling and understandable for those who use it, representative in the entire range of application, adequate enough to reflect the object under study with the required accuracy, and also oriented to the computational capabilities available to the researcher.

Establishing the general characteristics of the system allows you to choose a mathematical apparatus on the basis of which a mathematical model is built.

As can be seen from this scheme, the choice of a mathematical apparatus is not unambiguous and rigid. Thus, the apparatus of linear and nonlinear algebra, the theory of differential and integral equations, and the theory of automatic regulation can be used for deterministic objects.

An adequate mathematical apparatus for modeling probabilistic objects is the theory of deterministic and random automata with deterministic and random environments, the theory of random processes, the theory of Markov processes, heuristic programming, methods of information theory, methods of control theory and optimization.

The application of a mathematical model in research is often called a "computational experiment."

16.4 Abstract modeling

Abstract modeling is based on an analytical description of the investigated process or phenomenon, in the language of some scientific theory, most often mathematical.

The main stages of this type of modeling are as follows:

1) building a descriptive (informational) model of the process, i.e. a more clear and unambiguous description of what is happening and why, under what conditions the researched process is possible;

2) definition of the logical-mathematical model, that is, the translation of the information model into mathematical language;

3) study of the functioning of the model.

At the first stage, a clear and unambiguous verbal description of its information model is given: what is happening, why it is happening and under what conditions the researched process is possible.

At this stage of research, in-depth knowledge of the subject of study is required.

At the second, no less important stage, verbal descriptions (most often blurred, vague) are translated into the appropriate mathematical language. Thus, at the second stage, the information model of the process is transformed into a logical-mathematical model, presented in the form of appropriate rules and mathematical formulas.

The third stage of modeling is a study of the functioning of the model: its structure and parameters, properties and their similarity to the properties of the original process. This stage is much simpler than the two previous (creative) stages, especially if the researcher has electronic computing tools at hand.

Let's illustrate what has been said on the example of modeling an automatic control system.

Each element of the system has a completely defined physical nature. However, based on the behavior of elements in dynamic modes, it is possible to isolate the main characteristics of each of the elements, which do not depend on the features of the design, energy sources, etc., using an isolating abstraction. These characteristics can be expressed through constants, speeds, and accelerations.

After describing the behavior of each element of the system by an algebraic or differential equation together with some limiting conditions, we obtain a system of equations, which is an abstract model.

This model is isomorphic with a specific class of real systems that, at first glance, have nothing in common.

As an example, we can take the process of change in time of the current I(t) in an electric coil, which has an inductance L and an active resistance R, when it is connected to the clamp of an electric generator with a voltage U(t).

For the described information model of the process, in accordance with Kirchhoff's law, a differential equation can be formulated, which is its mathematical model

$$U(t) = R \cdot I(t) + L \cdot \frac{dI(t)}{dt}. \quad (16.2)$$

Then, with the help of this model, you can analytically or on a computer calculate the transient process of changing the current in the coil (it will grow exponentially) and determine the time constant that characterizes the inertia of the electric circuit in question

$$T = \frac{L}{R}. \quad (16.3)$$

Any mathematical formula in mechanics, physics, chemistry is a mathematical model of any process or phenomenon.

So, if V is the constant speed of, say, a car, and t is the time of movement, then the formula is

$$S = v \cdot t \quad (16.4)$$

is a mathematical model of the process of increasing the distance traveled by the car (S).

Analytical modeling.

The analysis of various physical and economic models of many researched processes is carried out using mathematical methods, which can be divided into the following main groups:

analytical research methods (elementary mathematics, differential and integral equations, calculus of variations and other sections of higher mathematics) used to study continuous deterministic processes;

methods of mathematical analysis using an experiment (method of analysis, theory of similarity, method of dimensions), etc.

With the help of analytical methods, the mathematical dependence between the parameters of the model is determined.

These methods make it possible to study processes in depth and comprehensively, to establish precise quantitative relationships between arguments and functions, and to analyze the studied phenomena.

Analytical dependencies make it possible to study processes in a general form on the basis of functional analysis of equations, which is a mathematical model of a certain class of specific processes.

An analytical model can be, for example, built in the physical domain. It is an abstract system consisting of a point mass (m), which rests on an inertialess linear spring (k) and is connected to a viscous damper (c).

A mathematical model in the time domain can be obtained by applying Newton's second law to an analytical model.

By comparing internal (inertia, damping and elasticity) and external forces, we obtain a mathematical model

$$m \cdot \ddot{x}(t) + c \cdot \dot{x}(t) + kx(t) = f(t). \tag{16.5}$$

This model is represented as a second-order differential equation.

A mathematical model can be specified using a functional relationship, in the form of a system of algebraic, differential or integral equations. Such models usually contain a large amount of information.

A characteristic feature of mathematical models is that they can be transformed with the help of a mathematical apparatus.

So, for example, functional dependencies can be simplified using algebraic transformations; differential or integral equations can be solved.

As a result, the researcher receives new information about the functional dependencies and properties of the models.

When choosing a method of analytical research, they are guided by the principle of correspondence between external and internal plausibility.

This principle is similar to the well-known rule of approximate calculations: the degree of accuracy of the calculations must correspond to the degree of accuracy of the initial data.

The choice of a mathematical model research method is more effective, the more clearly the goal is set and the more data there are about the final solution to the problem.

The scheme is based on the assumption of independence of vertical oscillations of the front and rear axles relative to the transverse axis of the car, which passes through the center of gravity of the sprung mass, and the symmetry of the car relative to the longitudinal axis.

When compiling the differential equations of the car's motion, neither the weight of the car nor the vertical reactions, which are equal to the product of the stiffness of the suspensions and their static deflection, are taken into account.

Calculation of forces and displacements is carried out from the "static level".

Forces directed downward are considered positive, and forces directed upward are considered negative.

Then you can write the system of differential equations in this form

$$M \cdot \ddot{z} + c \cdot \dot{z} + k \cdot z - c \cdot \dot{x} - k \cdot x = 0. \quad (16.6)$$

$$m \cdot \ddot{x} - c \cdot \dot{z} - k \cdot z + c \cdot \dot{x} - k_1 \cdot x + c_1 \cdot \dot{x} = k_1 \cdot q + c_1 \cdot \dot{q}. \quad (16.7)$$

Marking how $\frac{k}{M} = {w_o}^2, \frac{k}{m} = {w_1}^2, \frac{k_1}{m} = {w_2}^2, \frac{c}{M} = h_o, \frac{c}{m} = h_1,$ $\frac{c_1}{m} = h_2,\ w_k^2 = w_1^2 + w_2^2,$ we obtain the differential equations of motion of the body and wheels of the car

$$\ddot{z} + h_o \cdot \dot{z} + {w_o}^2 \cdot z - h_o \cdot \dot{x} - {w_o}^2 \cdot x = 0. \quad (16.8)$$

$$\begin{aligned} &\ddot{x} - h_1 \cdot \dot{x} - h_1 \cdot \dot{z} + h_2 \cdot \dot{x} - \\ &-{w_o}^2 \cdot x - w_1^2 \cdot z + w_2 \cdot x = \\ &= w_2^2 \cdot q + h_2 \cdot \dot{q}. \end{aligned} \quad (16.9)$$

The last equations make it possible to determine the displacement and acceleration of the body and wheels and their relative displacements when moving through an inequality of the form q = f(t) at different speeds.

The use of mathematical models is one of the main methods of modern scientific research.

But this approach also has important drawbacks. In order to find a specific one from the entire class of solutions that is specific only to this process, it is necessary to set the conditions of unambiguity.

Establishing boundary conditions requires conducting a reliable model experiment and careful analysis of experimental data.

Incorrect definition of the boundary conditions leads to the fact that the theoretical analysis is carried out not of the process that was planned, but of the already changed one.

In addition to the mentioned shortcomings of analytical methods, in many cases it is not always possible or impossible at all, or it is extremely difficult to find the final analytical expression, taking into account the conditions of unambiguity, which most accurately reflect the real physical essence of the investigated process.

Sometimes, when investigating a complex physical process with well-founded boundary conditions, the original differential equations are simplified due to the impossibility or excessive complexity of their solution, which distorts the physical essence of the process.

Thus, very often it is quite difficult to implement analytical approaches.

Analytical and experimental methods have their advantages and disadvantages, which often complicate the effective solution of practical problems.

The results of any experiment reflect the individual characteristics of the investigated process only.

They cannot be extended to another process, even close in physical essence. Therefore, the combination of positive aspects of both analytical and experimental research methods is extremely fruitful.

Phenomena, processes are studied not in isolation from each other, but in a complex manner. Various objects with their specific characteristics are combined into groups characterized by uniform laws. This allows you to extend the results of the analysis of one phenomenon to others, or even to a whole class of similar phenomena.

With this principle of conducting research, the number of parameters is reduced, they are replaced by generalized criteria.

As a result, the sought mathematical relationship between the parameters is simplified.

Methods of combining analytical means of research with experimental methods of analogy, dimensions, which are a type of modeling methods, are based on this principle.

An abstract mathematical system can be represented by a graph (goal tree), which consists of two sets: vertices and edges (see Fig. 3.6).

The mathematical theory of graphs is a rather convenient tool for describing the structures of complex technical systems.

Graphs are used in reliability theory and diagnostics to develop mathematical models of transitions of individual elements and systems as a whole from an operational to an inoperable state and to create a system of equations that describes these transitions.

The mathematical apparatus of graph theory allows to perform a numerical analysis of system reliability.

Control questions and tasks for self-study

1. What is a model?
2. What are the models?
3. What aspects of the research object should the model reflect?
4. What is the modeling of knowledge objects based on?
5. What is meant by abstract modeling?
6. What are the main stages of abstract modeling?
7. Give a simple analytical and mathematical model.
8. Give a scheme for building a mathematical model.
9. Describe the mathematical apparatus on the basis of which a mathematical model is built.
10. What are the disadvantages of analytical and experimental models?
11. Give structural models of processes.
12. What is physical modeling?
13. Give an analytical and mathematical model based on the principle of similarity of elastic systems: the conditions of rolling wheels on the road and on a stand with running drums.
14. Set the similarity coefficient, if the empirical comparative evaluation established that the rolling losses on the stand with the drum radius rb to the wheel radius rk are similar to the rolling losses in road conditions.

LIST OF REFERENCES

1. Основи наукової творчості: навч. посібник / С. М. Продащук, А. Л. Кравець, Г. Є. Богомазова та ін. – Харків: УкрДУЗТ, 2021. – 142с. – Режим доступу: http://lib.kart.edu.ua/bitstream/123456789/7440/1/Навчальний посібник

2. Основи наукових досліджень та інженерної творчості // Навчальний посібник для студентів напрямів підготовки 144 «Теплоенергетика». – К.: КПІ ім. Ігоря Сікорського, 2016. – 270 с. – Режим доступу: https://ela.kpi.ua/bitstream/123456789/19836/1Основи_наукових_досліджень_та_інженерної_творчості%28Енергетика%29.pdf

3. Методика та організація наукових досліджень : Навч. посіб. / С. Е. Важинський, Т І. Щербак. – Суми: СумДПУ імені А. С. Макаренка, 2016. – 260 с. – Режим доступу: https://pedagogy.lnu.edu.ua/wp-content/uploads/2017/03/vajinskii-posibnyk.pdf

4. Scientific method - Definition from the Merriam-Webster Online Dictionary. merriam-webster.com. (англійською). Архів оригіналу.

5. Discorsi e dimonstrazioni mathematiche intorno à due nuove scienze attenenti alla meccanica ed movimenti locali. Трактат «Бесіди і математичні обґрунтування двох нових наук, що стосуються механіки і законів падіння»: англ. переклад.

6. Т. Кун Логіка та методологія науки. Структура наукових революцій

7. Chakravartty, Anjan. Scientific Realism // The Stanford Encyclopedia of Philosophy (Summer 2011 Edition), Edward N. Zalta (ed.). - 2011.

8. Roberts, Mike (9 січня 2022). Why the Bastardization of the Scientific Method Is so Dangerous / Mike Roberts. fee.org (англ.).

9. Крушельницька О. В. Методологія та організація наукових досліджень: Навчальний посібник. – К.: Кондор, 2013. – 192 с.

10. Мигаль В. Д. Технічна кібернетика транспорту: Навч. посіб.– Х.: ВД «ІНЖЕК», 2007. – 328 с.

11. Петрук В.Г., Володарський Є.Т., Мокін В.Б. Основи науково-дослідної роботи: навч. Посіб. Під ред В.Г. Петрука. – Вінниця: Універсум, 2005. – 144с.

12. Цехмістрова Г. С. Основи наукових досліджень: Навч. посіб.– К.: ВД «Слово», 2004. – 240 с.

13. Мовчан В. П., Бережний М. М. Вступ до основ науково-технічної творчості: Монографія.– Дніпропетровськ: Пороги, 2002. – 240 с.

14. Кузнецов Ю. М. Теорія розв’язання творчих задач.– К.: ТОВ «ЗМОК»: ПП «ГНОЗІС», 2000.– 294 с.

15. Статистична обробка результатів експериментальних вимірювань: методичні рекомендації / В. П. Ржепецький. – Кривий Ріг : Криворізький державний педагогічний університет, 2011.

16. Методи обробки експериментальних даних з використанням MS Excel: Навчальний посібник / А.А. Горват, О.О. Молнар, В.В. Мінькович. – Ужгород: Видавництво УжНУ “Говерла”, 2019.

17. Офіційний сайт Харківського національного автомобільно-дорожнього університету [Електронний ресурс]. – Режим доступу до курсу «Теорія та методи наукової творчості (ЗА)»: https://dl2022.khadi.kharkov.ua/course/view.php?id=645