MINISTRY OF EDUCATION AND SCIENCE OF UKRAINE
NATIONAL UNIVERSITY
«YURI KONDRATYUK POLTAVA POLYTECHNIC»
Educational and Scientific Institute of Oil and Gas
Department of Drilling and Geology

METHODOLOGY OF SCIENTIFIC RESEARCH WORKS

Lecture notes
for students majoring in 185
Oil and Gas Engineering and Technology.
Degree of higher education – master

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Methodology of scientific research works: lecture notes for students majoring in 185 Oil and Gas Engineering and Technology. Degree of higher education – master. – Poltava: National University «Yuri Kondratyuk Poltava Polytechnic», 2022 – 69 p.

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Approved by the Scientific and Methodological Council of the Educational and Scientific Institute of Oil and Gas

Protocol from "02" August 2022 № 2

INTRODUCTION

The discipline "Methodology of scientific research works" is a selective discipline that should form in students a scientific approach when solving applied problems, in particular, in the field of oil and gas extraction.

The purpose of teaching this discipline is for students to learn fundamental information about the basic principles of the scientific approach when solving practical problems in the field of oil and gas extraction.

According to the requirements of the educational and professional program, as a result of studying the discipline, students must:

– **know**:

– modern methods of scientific research;

– the main principles of the organization of scientific and research work (SRW);

– the methodology of conducting scientific research;

– methods of searching and processing scientific information;

– features of planning and organization of theoretical and experimental research;

– features of the application of statistical methods of processing research results;

– the rules for processing the results of the SRW;

– **be able**:

– perform calculations using methods of scientific research;

– to prepare the results of scientific research.

– conduct theoretical and experimental research at the appropriate level, objectively evaluate the obtained scientific results based on the application of integrated knowledge of other disciplines and system analysis;

– think abstractly, analyze and synthesize;

– find, process and analyze information from various sources;

– verbally and in writing to present and discuss the results of scientific research and/or innovative developments;

– identify, set and solve research problems in the oil and gas field, evaluate and ensure the quality of the performed research.

LECTURE 1
Concept, content, purpose and functions of science.
The main stages of formation and development of science.
Historical background and the national system of classification of sciences.
Forms of organization and management of science, training and certification of scientific personnel

Science is a field of human activity, the main function of which is to identify and study objective laws with the aim of their practical application.

In the process of development of science, the following **transformations** take place:

• mathematization of sciences;

• differentiation due to inexhaustibility of objects of knowledge;

• integration, research at the junctions of different sciences, mutual borrowing of results;

• communication with technology and production, accelerated implementation of new scientific results.

A possible classification of scientific research and its connections with technology is presented in fig. 1.1.

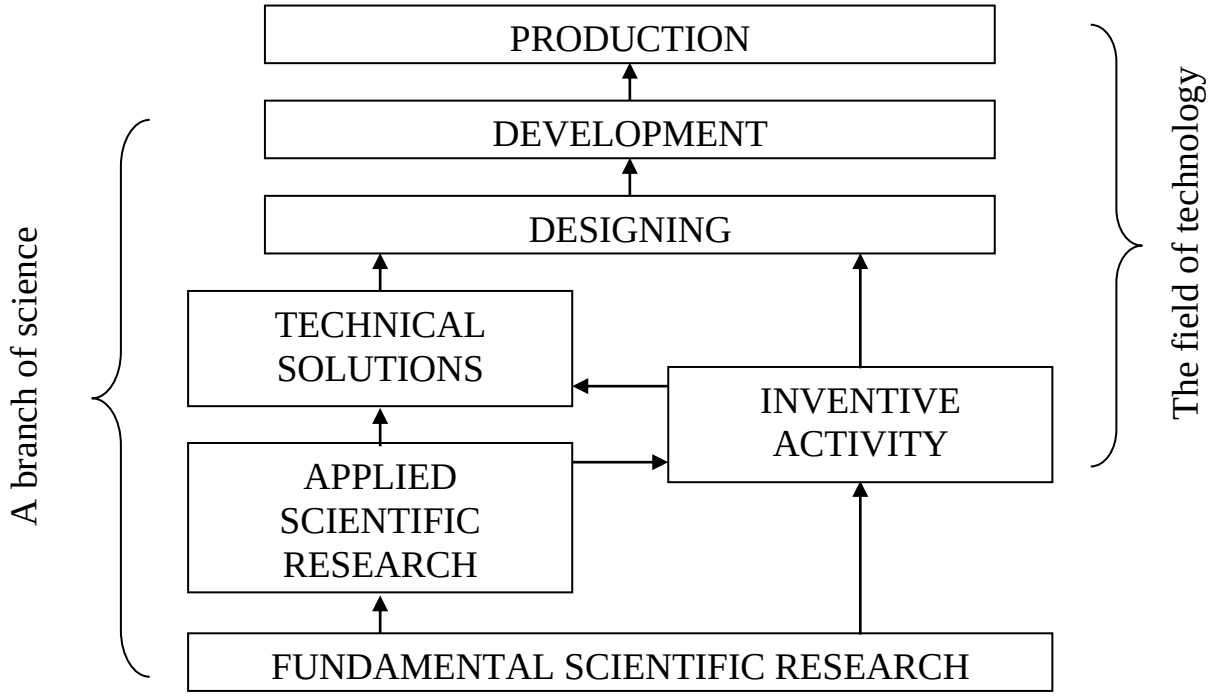


Fig. 1.1. The structure of scientific and technical research

It makes sense to conditionally divide scientific research into certain **levels**:

• **fundamental**, devoted to the study of the basic laws of nature (for example, mathematics, nuclear physics, chemistry, genetics, etc.). Fundamental research can

be exploratory (knowledge of the laws of nature without a specific practical goal) and targeted (defined object and ultimate goal of research). Basic research tasks are placed on the edge of knowledge, the probability of obtaining the desired result may be less than 10%;

• **applied ones** are performed in order to solve specific practical tasks and problems. As a rule, they are based on the application of the results of fundamental research to solve specific problems (problems) with specific objects. Applied research is always targeted.

• **technical developments** bring the results of applied research to the engineering level and implementation in production.

Usually, fundamental sciences are ahead of applied research, but the opposite is often the case: in the process of performing applied scientific developments, the topic of fundamental research is formulated.

The sphere of interests of an engineer and a scientist in the field of technology is applied scientific research and technical development, as well as design and implementation in production.

Applied and fundamental scientific research can be **theoretical** (acquiring new knowledge from the known through logically justified operations) or **experimental** (acquiring new knowledge through the generalization of experimental data). Often, theoretical and experimental methods of research are applied in a complex manner.

Individual tasks of theoretical research may require experimental data, or are more easily solved experimentally. An experiment can give impetus to theoretical development, and can serve to test a theory.

The classification of sciences by fields of knowledge (for example, biological, military geological, medical, pedagogical, technical physico-mathematical, economic, chemical and a number of others) is quite important, which is reflected in the names of scientific degrees (for example, candidate of economic sciences, doctor of technical sciences). There is also a state classification of scientific specialties. This classification allows distinguishing specialists, objects of research and systematizing scientific information, but scientific research can also be carried out at the intersection of sciences.

In the field of scientific research, **the state provides**:

• socio-economic, organizational and legal conditions for scientific activity;

• creation of science infrastructure, training of scientific personnel;

• funding of fundamental research and priority areas;

• information provision and assessment of the level of scientific research;

• implementation of scientific achievements, scientific relations with other states.

Scientific research is usually carried out:

• in specialized research institutions of the National Academy of Sciences (NAS) of Ukraine and other Academies;

• in branch research institutes under ministries and committees;

• in higher educational institutions, where, in particular, the majority of scientists of Ukraine work;

• by individual specialists in the process of preparing candidate and doctoral theses (such work is also performed in accordance with the plans of scientific work of research institutions and higher educational institutions).

Financing of scientific developments is carried out at the expense of the state, individual ministries and committees, enterprises, organizations and institutions.

The State Budget finances fundamental scientific research, priority areas of scientific development, applied research of national significance, as well as research carried out under international agreements. Applied scientific research and technical development are mainly financed by ministries and departments, enterprises, organizations and institutions.

Scientific work in state higher education institutions can be financed at the expense of the state budget (development to the order of the state represented by the Ministry of Education and Science and the second half of the teacher's working day), local authorities (regional scientific programs), legal entities and individuals (orders under economic contracts) .

The execution of scientific research on a certain topic (order) is entrusted to individual divisions of scientific research institutes or higher educational institutions, as well as to specially created temporary creative teams. As a rule, the implementation of specific work is organized by a scientific leader and a responsible executor, who manage a creative team consisting of scientific employees and auxiliary technical workers.

Scientific research is mainly carried out in universities, where specialized institutes, laboratories and temporary creative teams are created to carry out individual developments. Also, scientific research is carried out on the order of various companies and organizations, including state institutions.

The scientific potential of the state is developed through the training of scientific personnel in the system of educational and research institutions.

In the system of general secondary education, there are general educational institutions of the I-III degrees, which provide primary, basic and full secondary education without professional training. Vocational and technical secondary schools operating in the system of vocational and technical education provide full secondary education and vocational training for a qualified worker.

The higher education system consists of higher education institutions (HEIs) I–II (colleges, schools) and III–IV levels of accreditation (academies, universities), which provide basic or full higher education with the professional qualification of junior specialist, bachelor, specialist or master. For example, in a technical school (university I level of accreditation) you can get a full secondary education and the qualification of a junior specialist.

A full higher education with the qualification of a specialist can be obtained at a higher education institution of the III or IV level of accreditation, and with a master's qualification - at the IV level of accreditation of a specialty.

The highest rung of the educational "ladder" is the training of highly qualified scientific personnel (candidates and doctors of science).

In addition to the **scientific degrees** of candidate and doctor of sciences, there are also academic titles of senior researcher, associate professor, and professor in Ukraine.

By the way, in other countries there are different systems of attestation of scientific personnel: one academic degree of doctor, degrees of doctor of philosophy and doctor of sciences, master's degree and doctorate, etc.

The procedure for the attestation of scientific personnel is regulated by the "Regulations on the Awarding of Scientific Degrees and the Assignment of Academic Titles", approved by the Cabinet of Ministers of Ukraine. The scientific degrees of candidate and doctor of sciences are awarded on the basis of the public defense of the relevant dissertations in specialized academic councils. The network of such councils is created by the Higher Attestation Commission (HAC) of Ukraine on the basis of leading scientific institutions and universities of III-IV levels of accreditation. Each specialized academic council has the authority to review candidate's or doctoral dissertations in a certain scientific specialty or a number of specialties.

Candidates' council may include doctors and candidates of sciences; doctoral councils are formed exclusively from doctors of science in the relevant specialty. The HAC monitors the work of specialized councils and highlights the issue of certification of scientific personnel in its own printed publications.

A person with a complete higher education (specialist or master's degree) corresponding to the chosen scientific specialty has the right to defend a candidate's thesis. A doctoral dissertation is completed and defended by a candidate of sciences.

Preparation of a candidate's dissertation can be conducted in a full-time or part-time graduate school or by applicants attached to an institution that has a graduate school in the relevant specialty. A doctoral dissertation is prepared in a doctoral program or independently.

A candidate's thesis must have a scientific supervisor, and a doctoral thesis can have a scientific consultant. A candidate of science degree candidate takes candidate exams in philosophy, foreign language and specialty before defending the thesis.

According to the results of the candidate's thesis, at least three, and at least 20 scientific articles for the doctoral thesis must be published in publications recognized by the HAC as specialists in this specialty. Approbation of the dissertation work through reports at scientific conferences and in leading scientific institutions is mandatory.

Dissertation review procedure:

- examination in the institution on the basis of which the work was performed;
- submission to the specialized scientific council;

• preliminary review by a specially appointed commission of three council members;

• a report at a scientific seminar at the specialized council;

• appointment of official opponents and a leading scientific institution;

• publication of an announcement about protection;

• printing and sending the abstract of the dissertation;

• examination of the dissertation by official opponents and the leading institution;

• analysis of the abstract by leading specialists with feedback;

• public defense at the meeting of the specialized scientific council;

• preparation of the certification case;

• consideration of the certification case and dissertation at the HAC;

• if the decision of the specialized academic council is approved by the HAC, the recipient is awarded a doctor's or candidate of sciences diploma.

The procedure for reviewing dissertations is aimed at ensuring openness and the possibility of familiarizing a wide range of scientists with the submitted work and the level of scientific training of its author.

In the defense process, an in-depth analysis and assessment of the submitted thesis is carried out based on the applicant's speech, his answers to the questions, the publication of the reviews of the leading institution and reviews of the abstract, the speeches of official opponents and council members. Everyone present at the defense can ask questions or speak.

Procedural issues are quite fully set out in the above-mentioned "Regulations...", and the rules for writing dissertations and dissertation abstracts are in the document "Basic Requirements for Dissertations and Dissertation Abstracts" approved by the Supreme Court of Ukraine.

If scientific degrees testify to the **scientific qualification** of the employee and his ability to conduct scientific work, then academic titles are evidence of the professional qualification of a scientific or scientific-pedagogical worker in the chosen field of activity.

The academic title of senior researcher is awarded by the HAC to persons who have the scientific degree of candidate or doctor of sciences and work in relevant positions in scientific research institutions.

Academic titles of associate professor and professor are awarded by the Ministry of Education and Science of Ukraine to persons who have scientific degrees of candidate or doctor of sciences and are successfully working in relevant positions in higher educational institutions of III-IV levels of accreditation.

As an exception, in special cases determined by the "Regulations...", the academic title of professor may be awarded to candidates of sciences, and associate professor to teachers of higher educational institutions of III-IV levels of accreditation without a scientific degree.

Academic titles are assigned after consideration of attestation cases, in which the results of the professional activity of the awardees are summarized according to

the established form. The requirements for the recipients of academic degrees and the procedure for registration of attestation cases are set out in the "Regulations on the Awarding of Academic Degrees and Academic Degrees". Based on the results of the examination of the certification case, a certificate of a senior researcher, associate professor or professor is issued.

A full-fledged member (academician) or a corresponding member of the Academy of Sciences can become a doctor or a candidate of sciences who has great scientific achievements after being elected at the general meeting of the Academy.

In Ukraine, there are: National Academy of Sciences, Ukrainian Academy of Agrarian Sciences, Academy of Medical Sciences of Ukraine, Academy of Legal Sciences of Ukraine, Academy of Arts of Ukraine. The specified Academies of Sciences are state scientific institutions, the activities of which are financed from the state budget. The Academies of Sciences include specialized research institutes, branch and territorial departments.

Other branch Academies work under the rights of public organizations.

LECTURE 2
Concepts, features and methodology of scientific research. Classification of scientific research methods

Theoretical studies make it possible to acquire new knowledge from the known through logically justified operations.

They are characterized by **the following cognitive techniques**:

• **idealization**, abstraction from unimportant details, which simplifies the work, but may adversely affect the final results;

• **axiomatic** as based on the general laws of physics, chemistry, mathematics and other fundamental sciences;

• **hypothetical method**, which consists in formulating a hypothesis on the basis of known facts, and then proving its legitimacy;

• **deduction** (deduction of individual provisions from general laws) and **induction** (establishment of general regularities based on individual facts);

• **analysis** (division of the phenomenon into its component parts) and **synthesis** (combination of individual facts into a coherent picture of the studied phenomenon);

• **formalization**, description of the studied phenomenon with conceptual or mathematical models (physical models are the subject of experimental methods).

Analytical research methods are used when the phenomenon under study can be described by a strict and complete mathematical model (for example, algebraic or differential equations and systems).

To take into account random factors, **probabilistic methods** are used.

Optimization methods are widely used, which make it possible to find optimal solutions to structural, technological and other problems.

Research on the interaction of research objects is carried out by **methods of system analysis**.

If the mathematical model is very complex, not fully understood, or the current level of development of mathematics does not allow obtaining a closed analytical solution, **numerical experiments** are conducted using algorithmic models and subsequent generalization of the results. This is appropriate in the case when it is impossible to obtain the necessary analytical dependencies, but it is possible to calculate the reaction of the experimental system to specific numerical values of the input influences.

Modern theories usually consist of the following **components**:

• **original experimental base** (facts that require explanation);

• **original theoretical base** (set of postulates, axioms, fundamental laws and proposed hypotheses);

• **the methodology and logic of the theory as a set of rules for operating with information and ways of proving the put forward hypotheses**;

• **theoretically derived statements and scientific conclusions with their proofs**.

In the process of theoretical research, individual questions can be solved experimentally (obtaining the necessary factual data, studying the reaction of complex systems under various influences, checking theoretical conclusions, etc.).

The obtained experimental dependences can be described by analytical expressions and further research can be continued by theoretical methods.

Experimental studies ensure the acquisition of new knowledge by summarizing experimental data.

They are performed in order to collect information about the subject of research, to study complex systems, the reaction of which cannot be described analytically, as well as to test the theory.

Their tasks, volume and methodology mainly depend on the purpose of experimental research.

Experiments are divided into:

• **active** (specially planned experiments);

• **passive** (observation of real phenomena), artificial (testing samples in the laboratory);

• **natural;**

• **laboratory;**

• **production.**

The vast majority of experimental research includes the following stages:

• **setting tasks and developing an experiment program;**

• **selection of experimental tools** (samples, equipment, measuring tools, etc.);

• **preliminary studies to clarify the experimental program;**

• **conducting research and preliminary processing of results;**

• **detailed processing and analysis of experiment results;**

• **verification of the reliability of the results** (most often this is carried out by statistical processing of the obtained experimental data).

The experimental program may include the following components:

• the scope of tests (it is usually determined on the basis of the planning of single-factor or multi-factor experiments);

• scheme of experimental setup and drawing of samples;

• means of creating the necessary effects on the research object;

• means of measurement and schemes of their establishment;

• procedure for conducting tests;

• procedure for recording and operational processing of measurement results;

• method of final processing of experiment results, etc.

When developing a program of experimental research, mathematical methods of experiment planning are usually used, which allow obtaining the

necessary results with minimal costs.

These methods are most fully developed and tested a lot for planning experiments with the aim of finding optimal solutions. Statistical methods of experiment planning make it possible to estimate the probable errors of the results or, conversely, to predict the volume of experimental studies (number of samples, number of measurements, etc.) necessary to achieve the specified accuracy of the results.

To process experimental data, well-proven **methods of mathematical statistics** are widely used, which make it possible to generalize the results of research, obtain the necessary regularities, and justify the decisions made.

Processing of experimental data is carried out with the help of modern computer technology, which ensures the accumulation of results, management of the course of the experiment based on the operational processing of the received data, as well as detailed processing and analysis of the results at the final stage of experimental research.

According to the results of the experiment, new theories are usually developed or existing ones are tested.

To check the reliability of the obtained data, it is very useful to compare them with the results of research by other authors.

LECTURE 3
Hypotheses in scientific research and their proof. An experiment in scientific research. Mathematical planning of the experiment

A hypothesis is a system of inferences, scientific assumptions, with the help of which, on the basis of a number of facts, a conclusion is made about the existence of an object, connection or cause of a phenomenon, and this conclusion is not absolutely reliable.

The need for a hypothesis arises in science when there is an unclear connection between phenomena, their cause, although many circumstances that precede or accompany it are known; when it is necessary to establish a picture of the past based on some characteristics of the present; on the basis of the past and the present, it is necessary to draw a conclusion about the future development of the phenomenon.

The hypothesis has a probable character and requires verification and proof. After such verification, the hypothesis either becomes a scientific theory or is modified.

Experiment planning is a complex procedure for determining the number of experiments and the conditions for conducting them, sufficient to solve the task.

Experimental studies are usually performed to investigate the influence of certain factors (factors) on the selected resulting function.

A typical example can be the analysis of the influence of a number of parameters on the load-bearing capacity of the structure or the study of the dependence of a certain technical characteristic of a composite material on the quantitative ratio of its components. At the same time, the task of finding the ratio of factors can be set, in which the resulting function takes the required value (maximum, minimum or specified).

In particular, in the simplest case of one influencing factor, to find the extremum of the resulting function, it is enough to conduct several experiments at different values of this factor. In the presence of several influencing factors, all combinations of possible values of these factors should be considered.

Such an approach, called **a full factorial experiment**, may require a significant, sometimes practically impossible, number of experiments. In particular, with five values of three factors, $5^3=125$ experiments should be conducted, and, for example, in the case of five factors, the number of experiments increases to $5^5=3125$.

A significant reduction in the number of experiments is achieved by using well-tested methods of mathematical planning of the experiment, the main idea of which is to replace the real dependence of the resulting function on the influencing factors with simple approximations.

This principle, in particular, is illustrated in fig. 3.1, which shows the dependence of the resulting function **Y** on the influencing factor that varies within $1 \le \mathbf{X} \le 9$.

A complete factorial experiment of 9 trials with **X** = 1, 2, … 9 gave a minimum value of $\mathbf{Y_{min}}$=3 with $\mathbf{X_{opt}}$=4.

The second-order plan involves approximating the studied dependence with a square parabola, for which it is enough to conduct three experiments at the average and limit values of the influencing factor **X** = 1, 5, 9.

Considering the minimum of the obtained parabola as the sought optimal solution, we take $\mathbf{Y_{min}}$=3.9 at $\mathbf{X_{opt}}$=4.6

Thus, with a slight deviation from the real optimum, it was possible to reduce the number of experiments from 9 to 3.

The increase in the number of influencing factors leads to an even greater reduction (by tens and hundreds of times) of the volumes of multifactorial planned experiments compared to full ones.

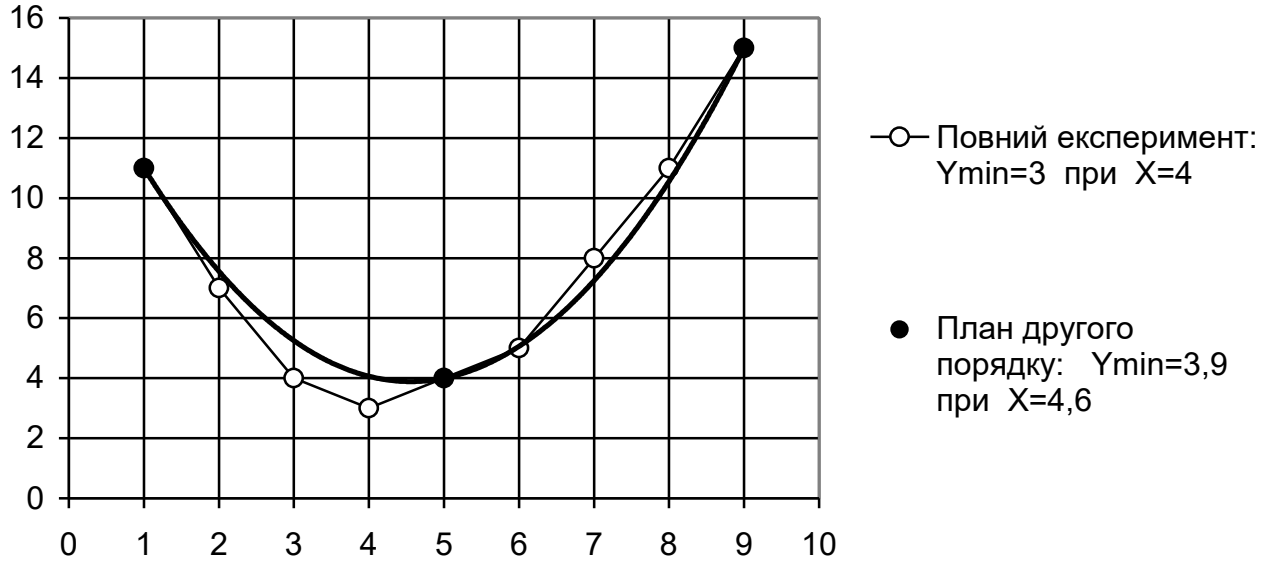


Fig. 3.1. Results of a full factorial and planned experiment:
black dots are a complete experiment ($\mathbf{Y_{min}}$=3 with $\mathbf{X_{opt}}$=4);
transparent points are second-order plan ($\mathbf{Y_{min}}$=3,9 at $\mathbf{X_{opt}}$=4,6)

Planning and conducting so-called factorial experiments, in particular, boils down to the following algorithm:

• choose the order of the plan (in the first case, approximation is carried out by linear functions, in the second case by square parabolas);

• determine the absolute limits of variation and relative levels of each factor (minimum –1, average 0, maximum +1);

• choose the type of plan and make a so-called planning matrix, each row of which defines one experiment and contains the values of the levels of all factors;

• according to the planning matrix, samples are prepared and tests or measurements of the values of the resulting function are carried out;

• statistical processing of the results is carried out according to the proven methodology, which, in particular, can be implemented in the environment of the EXCEL table processor or another previously proven mathematical program.

Thus, according to the results of statistical processing of the results of factorial experiments, parameters $\mathbf{A_i}$ of linear (for first-order plans) or quadratic (for second-order plans) **dependence of the resulting function on the influencing factors are obtained**.

So, for example, for a two-factor plan of the second order, you can get an equation of the following form

$$\mathbf{Y = A_0 + A_1X_1 + A_2X_2 + A_3X_1^2 + A_4X_2^2 + A_5X_1X_2} \ , \qquad (3.1)$$

where $\mathbf{X_1}$, $\mathbf{X_2}$ – the value of both factors;

$\mathbf{A_0}$ – $\mathbf{A_5}$ – parameters obtained as a result of processing the results of factorial experiments.

So, empirical dependencies of the form (3.1) allow analyzing the behavior of the studied system by estimating the value of the resulting function for various combinations of the values of the influencing factors.

It also makes sense to solve the so-called "inverse problem of finding the optimal combination of factors" that corresponds to the given value of the resulting function, in particular, to establish the ratio of the number of components that ensures the maximum strength of the composite material, etc.

LECTURE 4
Classification and main stages of research work. Formation of the topic, goal and tasks of scientific research

All scientific research is carried out in a certain sequence, which can be divided into the following stages:

1. **Choosing a research topic**. The topic of applied research is chosen based on the practical needs of society. To do this, an analysis of the relevant field of technology, an analysis of literary sources, substantiate the scientific relevance, practical expediency, the field of implementation of the results and the possible effectiveness of work are conducted.

They develop an indicative research plan, evaluate the reality of its successful implementation, the possible complexity and cost.

2. **Study of the state of the problem**. A detailed analysis of literary sources, the results of previously performed research and practical experience in the chosen field is carried out. Based on the results of the analysis, the first section of the scientific and technical report (dissertation, master's thesis, etc.) is usually compiled.

3. **Formulation of the goal and tasks of the work** is carried out based on the results of the analytical analysis of literary sources and the first section of the scientific and technical report (dissertation, master's thesis, etc.) is completed.

4. **Carrying out research**. According to the tasks, the necessary theoretical and experimental studies are carried out, which should be organically combined with the aim of achieving the set goal. Tasks, methodology and scope of research can be adjusted taking into account the obtained results.

5. **Completion and registration of work**. At this stage, they perform an analysis of the obtained results, formulate scientific conclusions, develop recommendations for the practical use of research results, formulate qualifying features of the work (object of research, subject of research, scientific novelty of research, their practical significance, personal contribution to the author, etc.).

It should be added that there may be a need for additional research and work. Compile and edit a work report (master's thesis, dissertation, scientific and technical report, scientific publication, etc.), in which the tasks, methodology and research results, scientific conclusions and practical recommendations, etc. are comprehensively explained.

6. **Implementation and scientific support of the work**. Usually, authors of scientific development participate in the implementation of research results in the relevant field of technology. At the same time, it often makes sense not only to specify, detail and explain the obtained results, but also to participate in the development of design documentation, to perform additional research, to set up experiments in production conditions.

Scientific development support is carried out already during the period of serial production and use of products and can be reduced to monitoring the quality of

production, solving problematic issues, modifying products taking into account the acquired production experience and customer feedback.

The relevance and expediency of the work is substantiated by a critical analysis of the modern level of technology and known scientific and engineering solutions.

The goal of scientific research is formulated as the final result that must be achieved as a result of its implementation.

An example of the formulation of the goal of scientific research (master's thesis):

- to improve the possibilities of using biopolymeric drilling fluids to preserve the primary permeability of the rock during the opening of productive reservoirs by the well and increase the efficiency of sludge removal from it.

The tasks of scientific research are a list of works that must be performed to achieve the set goal. They arise from the state of the scientific problem or problem (which has been solved completely, partially or not) and the goal of the research.

The object of research is a process or phenomenon that creates a problem situation and is therefore chosen for study.

An example of the wording of the research object (master's thesis):

– the interaction of biopolymer drilling fluids with unstable clay rocks during the opening of collectors by a well.

The subject of research is contained within the scope of the object and essentially determines the topic of the scientific work.

An example of the formulation of the research subject (master's thesis):

– phenomenological dependences of rheological parameters for different compositions of biopolymeric drilling fluids.

The prerequisites of the research determine its theoretical and experimental basis.

The purpose, task, object and subject of research must be determined before starting any scientific work.

The qualifications listed below give a general description of the scientific work and are finally formulated after the completion of the research. They are mandatory for theses for obtaining scientific degrees of candidate or doctor of sciences, as well as for master's theses.

The complete list and rules for formulating the qualification features of dissertation works are contained in the "Basic Requirements for Dissertations and Dissertation Abstracts".

Below is **a list of classification features of scientific research** with brief comments and examples of wording.

• **The connection of the work with scientific programs, plans, topics** characterizes the place of the submitted work in the general directions of scientific research.

• **Research methods** are listed with a definition of what exactly was studied by this or that method.

An example of the formulation of research methods (master's thesis):

– a method of planning single-factor and multi-factor experiments tested for scientific practice; normative laboratory methods for researching the parameters of water-based drilling fluids; methods of mathematical statistics for processing the results of experiments.

• **The scientific novelty of the obtained results** is presented in the form of an annotation of new scientific provisions and solutions, their differences from known ones and the degree of novelty (obtained for the first time, improved, received further development).

Examples of formulations of the beginning of scientific novelty (master's thesis):

– received new research data on ...;

– received new dependencies ...;

- improved methodology ...;

– a method of specifying ... was developed;

– justified and improved constructive and technological solution ...;

• **The practical value of the obtained results** (methods, devices, techniques, schemes, information, etc.) is presented with an assessment of the degree of their novelty and readiness for use or the fact of use.

An example of the formulation of the beginning of the practical significance of the obtained results (master's thesis):

- the practical significance of the obtained results lies in the development of recommendations for improving efficiency ...

• **Validity of scientific provisions, conclusions and recommendations.**

An example of the formulation of the reliability of scientific statements, conclusions and recommendations (master's thesis):

- the reliability of scientific statements, conclusions and recommendations is determined by the modern level of analytical and sufficient volume of experimental studies performed on modern certified equipment, the high degree of convergence of these results and the reproducibility of the obtained data.

• **The author's personal contribution** to the completed research and scientific works published with co-authors.

Usually, points of the author's personal contribution correspond to the scientific novelty of the obtained results.

• **Approbation and publication of work results** (at which scientific conferences the research results were presented and where they were published).

• **The structure of the work** indicating the total volume in pages, the number of sections, tables, figures, used literary sources, appendices.

The listed qualifications are usually given in the introduction to the master's work (dissertation, report).

In addition, they compose **an abstract of the work** with a concise statement of the prerequisites, main research methods, conclusions, scientific and practical results,

keywords for automated scientific information retrieval systems.

Sometimes it makes sense to present on a separate figure the structural diagram of research presented in a master's thesis (dissertation, etc.).

LECTURE 5
Scientific research work of students. Basic concepts of mathematical statistics. Laws of random variable distribution

The complexity and multifactorial processes taking place in society, nature and technology often lead to unpredictability of their results. Such processes, phenomena, events and quantities are called random and are analyzed using the methods of probability theory and mathematical statistics.

The simplest concepts and methods of statistical analysis are offered below, the application of which allows obtaining a number of practically useful results, and can also serve as a basis for a deeper study of probabilistic statistical methods based on the relevant literature.

An event that may or may not occur as a result of an experiment is called random.

An objective numerical measure of the possibility of realization of a random event is its **probability P**, which can take values ranging from zero for an impossible event to one for a reliable event.

An event with a probability of realization of $P \approx 0$ is considered practically impossible, and an event with $P \approx 1$ is considered practically reliable. The permissible deviation of the probability from zero or one depends on the significance and consequences of the event.

The results of observations or experiments are often values whose values cannot be predicted before the experiment. Such values are called **random (RV)**.

The set of values that a random variable can take as a result of an experiment forms **the domain of the random variable**.

In technology, **continuous random variables** are more common, the field of definition of which is real numbers.

Each conducted experiment (measurement) gives one specific value of the measured value, which is called **the implementation of a random variable**.

As a result of conducting a series of experiments, a set of values of a random variable is formed, which is called **a sample**. **The sample size** is equal to the number of available values of the random variable in the sample.

The set of all possible realizations of a random variable is called **the general population**.

The main task of statistical data analysis is to develop probabilistic models (dependencies, algorithms, methods, etc.) that describe the studied phenomena taking into account their random nature.

Such models allow predicting the probabilities of random events, predicting the possible values of random variables, evaluating the level of quality and reliability of products, and analyzing the expediency of engineering and management solutions.

The subject of mathematical statistics is also the planning of the necessary scope of the experiment, assessment of the accuracy of observations, correspondence of the theory to the experiment.

Statistical methods make it possible to establish the absence or presence of a relationship between random variables and obtain dependencies that make it possible to predict the value of one variable based on the results of observations of others, as well as to solve many other practically important problems.

Statistical processing of samples of random variables is usually performed on personal computers using ready-made programs. Small samples can also be processed using an engineering calculator with a built-in statistics mode.

Below are recommended methods of statistical data processing in the EXCEL spreadsheet environment, which has a number of built-in statistical functions. Their application is illustrated by a numerical example of statistical processing of a sample of a random variable.

The subject of statistical analysis is a sample of values of a random variable obtained as a result of measurements or observations.

The ultimate goal of statistical processing is to establish numerical characteristics and the distribution law of a random variable based on the available experimental data.

Let us denote the volume of the sample by **N**, and each of its elements (obtained as a result of a separate measurement of the value of a random variable) by $\mathbf{X_i}$. Numerical characteristics of a sample of a random variable can be determined using the built-in functions of the EXCEL word processor or other application programs that implement calculations according to the following formulas.

In EXCEL, the "list" argument of all functions for calculating statistical characteristics usually specifies the area of the worksheet, in the cells of which the sample elements are entered.

To define the list, simply "circle" the required area with the mouse cursor while entering the function through the "INSERT, FUNCTION" menu.

Because statistical functions ignore empty cells, the "list" worksheet area can be larger than the available sample. This allows you to create forms in which it is enough to enter data in order to perform their statistical processing.

The sample size is given by the smallest $\mathbf{X_{min}}$ and largest $\mathbf{X_{max}}$ observed values.

In the EXCEL environment, the functions MIN (list) and MAX (list) are used.

The average value (estimate of mathematical expectation), which determines the position of the center of the distribution of a random variable, is equal to

$$\mathbf{M} = \frac{1}{\mathbf{N}} \sum_{\mathbf{i=1}}^{\mathbf{N}} \mathbf{X_i} \qquad (5.1)$$

and in the EXCEL environment, it is calculated using the VALUE (list) function.

The standard or mean square deviation characterizes the degree of spread of a random variable relative to the center of the distribution and is calculated by the formula

$$\mathbf{S} = \sqrt{\frac{1}{\mathbf{N-1}} \sum_{\mathbf{i=1}}^{\mathbf{N}} \left(\mathbf{X_i - M}\right)^2} \quad , \qquad (5.2)$$

which in the EXCEL environment is implemented by the STANDARD DEVIATION function (list).

The coefficient of variation is a relative measure of the dispersion of a random variable and is determined by the formula

$$\mathbf{V = S/M}. \qquad (5.3)$$

The quantities included in the formulas (5.1) – (5.3) are explained above, where the volume of the sample is denoted by **N**, and each of its elements is denoted by $\mathbf{X_i}$.

The mean and standard have the dimension of the random variable itself.

The coefficient of variation is a dimensionless quantity expressed as a percentage. So, for example, the normative value of the coefficient of variation of concrete strength is set equal to **V**=0.135=13.5%.

In addition, variance $\mathbf{D = S^2}$, as well as coefficients of asymmetry and kurtosis are used in mathematical statistics.

For the purpose of illustration, we will consider a simple **example**, which, by the way, will be used when considering the following questions and at the same time will be highlighted in italics.

By surveying a group of 20 students, the time spent by each of them on course work was established.

As a result, a sample of N=20 values of time consumption in hours was obtained:

16	*20*	*27*	*27*	*25*	*14*	*13*	*31*	*24*	*19*
19	*21*	*16*	*17*	*26*	*21*	*18*	*23*	*20*	*22*

Processing according to the method described above gave the following results:

- *sample size X_{min} = 13 hours, X_{max} = 31 hours;*
- *average value (5.1) M = 20,95 hours;*
- *standard (5.2) S = 4,73 hours;*
- *coefficient of variation (5.3) V = 0,226=22,6%.*

Thus, different students spent from 13 to 31 hours on course work, the average time spent by the group was approximately 21 hours, and the coefficient of variation was 22.6%.

An exhaustive characteristic of a random variable is its **distribution law**, which establishes the relationship between the values of the random variable and the probabilities of their realization.

The distribution law of a continuous random variable can be specified in the form of a distribution function or a probability density.

The distribution function F(x) is equal to the probability that the random variable X will take a value less than x:

$$\mathbf{F(x) = P\{X < x\}}\,, \tag{5.4}$$

where **X** and **x** – random variable and its specific value;

$\mathbf{P\{.\}}$ – the probability of the event written in curly brackets.

The distribution function within the domain of the random variable increases monotonically from zero to one.

If the definition domain of the random variable is limited $\mathbf{a \le X < b}$, then $\mathbf{F(a) = 0}$, $\mathbf{F(b) = 1}$.

With an infinite domain of definition $\mathbf{F(-\infty) = 0}$, $\mathbf{F(+\infty) = 1}$.

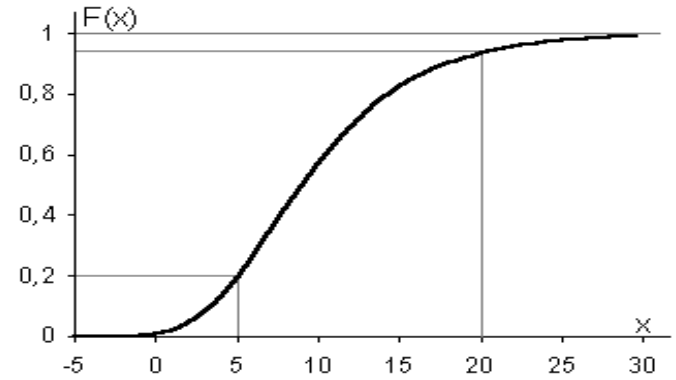
The first derivative of the distribution function is called **the probability density**, or **the distribution density**.

The probability density **f(x)** indicates the probability of realization of values of a random variable in the vicinity of ***x***.

Probability density graphs can have a diverse character, but all of them must lie above the abscissa axis and satisfy the normalization condition

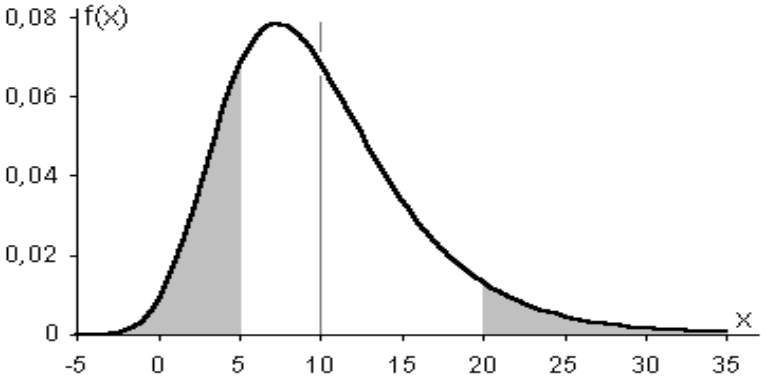
$$\mathbf{f(x) \ge 0}\;; \qquad \int_{-\infty}^{+\infty} \mathbf{f(x)\,dx = 1}. \tag{5.5}$$

A typical example of the function and distribution density of a random variable with an unlimited definition area is shown in Fig. 5.1.



a) distribution function
Gumbel
with characteristics:
M=10; S=6;
F(5)=0,195; F(20)=0,936

а



b) density distribution
Gumbel
with characteristics:
M=10; S=6;
P{x<5)=F(5)=0,195;
P{x>20)=1–F(20)=0,064

б

Fig. 5.1. Function and density of the distribution of a continuous random variable

The most likely values are between about 5 and 15, and the probability of other values decreasing as you move away from this range.

The density and the distribution function are related by ratios

$$\mathbf{f(x) = F'(x) = \frac{\partial F(x)}{\partial x}}\ ; \qquad \mathbf{F(x) = \int_{-\infty}^{x} f(t)dt}\ , \tag{5.6}$$

due to the nature of which the distribution function **F(x)** is sometimes called **the integral distribution function**/

The relationship between the density and the distribution function is shown in Fig. 5.3.

As follows from formula (5.6), the area marked on the graph of the probability density of the region ***x***<5 is equal to the value of the distribution function **F**(5)=0,195/

The statistical equivalent of the distribution density of a random variable is the histogram of the distribution.

Construction of a histogram of the distribution begins with the definition of the sample span as the interval between the smallest $\mathbf{X_{min}}$ and the largest $\mathbf{X_{min}}$ of the observed values.

The domain of the random variable obtained in this way is divided into intervals, the number of which **L** is chosen depending on the sample size **N** according to the recommendation of the table. 5.1.

Table 5.1

Division of a sample of a random variable into intervals depending on its volume

N =	10 – 40	40 – 100	100 – 300	300 – 1000	1000 – 5000
L =	4 – 6	5 – 8	6 – 10	8 – 15	10 – 25

The limits of intervals $\mathbf{C_j}$**, j=0,…,L** are established based on the length of the interval calculated by the formula

$$\mathbf{d = \left(X_{max} - X_{min}\right)/L} \tag{5.7}$$

and rounded to a value convenient for further use.

The lower limit of the first $\mathbf{C_0}$ interval is rounded down, and the upper limit of the last $\mathbf{C_L}$ is rounded up. Rounding off the length of the interval **d** can lead to an adjustment of their number **L**.

Construction of a distribution histogram is reduced to counting the amount of data $\mathbf{N_j}$ that belong to each of the selected intervals. This is done by reviewing the sample manually or using a computer.

Extreme intervals that contain little data are recommended to be combined. The length of the merged interval is equal to the sum of the lengths, and the amount of data is the sum of the amounts of data for the intervals being merged.

It is desirable that there should be no less than 3-5 data in each interval. Merging the intervals leads to smoothing of the histogram of the distribution and thus allows you to differentiate from random fluctuations in the frequencies of hitting the intervals with small sample sizes.

The probability of hitting each of the intervals (data frequencies) $\mathbf{P_j}$ is determined by dividing the corresponding amounts of data $\mathbf{N_j}$ by the sample size **N**

$$\mathbf{P_j = N_j / N}. \tag{5.8}$$

The probability density in each interval is the result of dividing the frequency $\mathbf{P_j}$ by the length of the given interval $\mathbf{d_j = C_j - C_{j-1}}$

$$\mathbf{f_j = P_j / d_j = P_j / \left(C_j - C_{j-1}\right)}. \tag{5.9}$$

At the same time, it should be remembered that different intervals can have different lengths.

To build a distribution histogram in the EXCEL spreadsheet environment, the FREQUENCY (list, C_J) function is used, which calculates the amount of data in the "lists" area smaller than the specified limit of the jth $\mathbf{C_J}$ interval.

*Continuing the previous numerical **example**, let's build a histogram of the distribution of time spent by students on course work.*

With N=20 data, we accept 6 intervals, the length of which according to formula (5.7) is equal to d=(31-13)/6=3.0 hours.

Having set the limits of C_J intervals in multiples of 3 hours, we get 7 intervals ranging from C_0=12 to C_7=33 hours.

The calculations necessary to construct a distribution histogram are performed in the table. 5.2.

Table 5.2

Calculations required to construct a histogram of the distribution of a random variable (in the example)

*Interval number **J***	*End of interval C_j*	N_j	P_j	f_j	f_{jt}
1	*15*	*2*	*0,10*	*0,0333*	*0,0383*
2	*18*	*3*	*0,15*	*0,0500*	*0,0696*
3	*21*	*5*	*0,25*	*0,0833*	*0,0846*
4	*24*	*4*	*0,20*	*0,0667*	*0,0687*
5	*27*	*3*	*0,15*	*0,0500*	*0,0373*
6	*33*	*3*	*0,15*	*0,0250*	*0,0033*

Since only one sampling element got to the last, seventh interval, this interval is combined with the sixth, the length of which thus increased to 6 hours.

The values of the hit probability P_j and distribution density f_j for each of the six intervals calculated by formulas (5.8) and (5.9) are also given in the table.

The graphic representation of the histogram, an example of which according to the data in the table is shown in Fig. 5.2, allows you to visually identify the nature of the density of the distribution of a random variable.

Along the abscissa axis are the ends of the C_j intervals, that is, the values of the random variable itself, and along the ordinate axis are the values of the probability density f_j calculated by formula (5.9).

From Fig. 5.2, it can be seen that the resulting histogram has a fairly symmetrical hill-like appearance.

The most likely time values are from 15 to 27 hours.

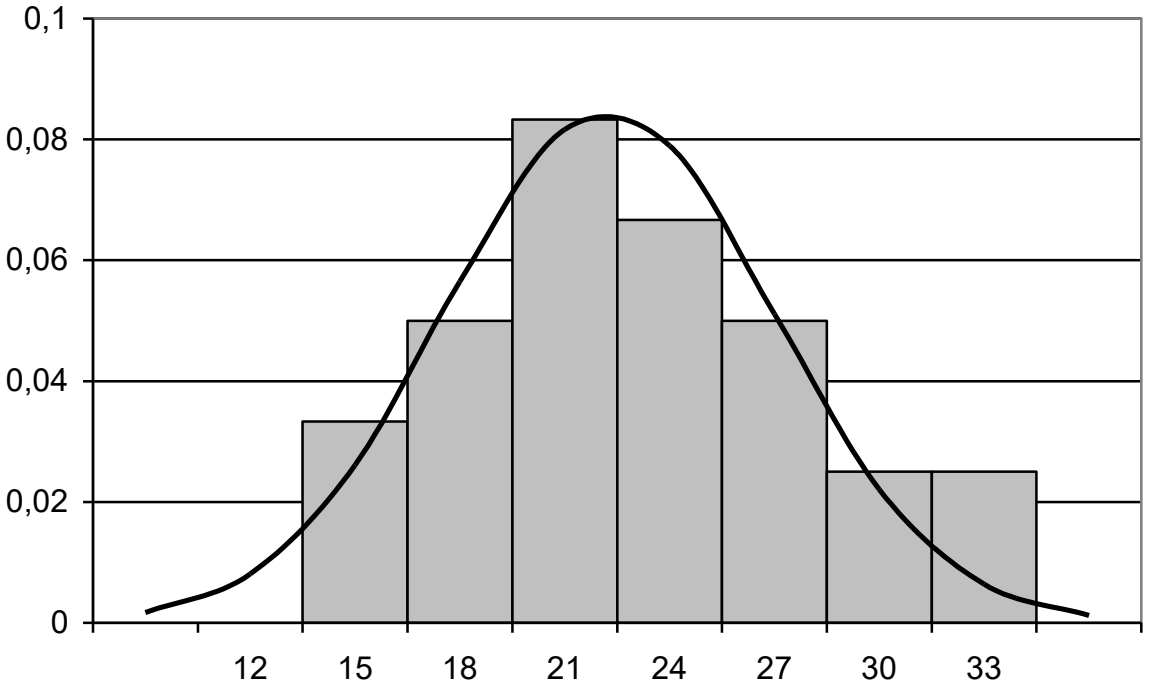


Fig. 5.2. An example of a histogram of the distribution of time spent on course work

The numerical characteristics obtained above and the histogram of the sample distribution allow us to describe the experimental data by the theoretical distribution law. To do this, it is necessary to select its type, define the parameters and check the consistency with the experimental histogram.

The type of theoretical distribution is chosen taking into account the physical justification of the experimental phenomenon and the appearance of the histogram, and the ratio of numerical characteristics can serve as additional evidence of its suitability.

The parameters of the selected distribution law are determined by the method of moments, which ensures the equality of the numerical characteristics of the theoretical distribution and the analyzed sample.

From the huge number of known distribution laws, we will consider three that are very often used in technical research: normal, Gumbel and exponential.

The normal distribution law (Gaussian distribution) is the limiting distribution to which the sum of many random variables approaches. Random variables, which are formed as a result of the influence of many random factors, are often distributed according to a normal law. This explains its wide application in various fields of science and technology.

Graphs of the density of the normal distribution, an example of which is shown in Fig. 5.2, have a symmetrical hill-like appearance and are given by the formula

$$\mathbf{f(x)=\frac{1}{S\sqrt{2\pi}}\exp\left[-\frac{(x-M)^2}{2S^2}\right]}, \qquad (5.10)$$

where **M** and **S** – mathematical expectation (average value) and standard obtained as a result of statistical processing of the sample.

The normal distribution function **F(t)** does not have an analytical expression and is determined according to statistical tables depending on the normalized value of the random variable

$$\mathbf{t=(x-M)/S}\ . \qquad (5.11)$$

The same tables allow solving the inverse problem: determining the normalized argument **t** based on the given value of the distribution function **F(t)**. When using tables, you should remember that $\mathbf{F(-t)=1-F(t)}$.

For calculations on a computer using the EXCEL spreadsheet processor, you can also use the statistical functions NORMRASP (X, M, S) and NORMOBR (F, M, S).

Gumbel's law of distribution (double exponential distribution) is the marginal distribution of the maximum sample element of a random variable, which explains its wide application to describe the extreme values of various quantities. The density and the Gumbel distribution function are equal

$$\mathbf{f(x)=\frac{1}{\beta}\exp\left[\frac{\alpha-x}{\beta}-\exp\left(\frac{\alpha-x}{\beta}\right)\right]}; \qquad (5.12)$$

$$\mathbf{F(x)=\exp\left[-\exp\left(\frac{\alpha-x}{\beta}\right)\right]}, \qquad (5.13)$$

where α and β – parameters that are approximately determined by formulas

$$\alpha=\mathbf{M-0{,}45\ S}\ ; \qquad \beta=\mathbf{0{,}78\ S}\ . \qquad (5.14)$$

The area of determination of the Gumbel distribution is infinite, and the one shown in Fig. 5.1, the probability density graph has a constant right-sided asymmetry with an asymmetry coefficient A=1.14.

The exponential law of distribution is widely used in the theory of mass service, the theory of reliability and in other branches of science. It is defined in the domain of positive real numbers with density and distribution function

$$\mathbf{f(x) = \beta\, e^{-\beta x}}; \qquad \mathbf{F(x) = 1 - e^{-\beta x}}\ , \tag{5.15}$$

where $\beta = 1/M$ – a parameter inversely proportional to the mathematical expectation.

An example of the density of the exponential distribution is shown in Fig. 5.3.

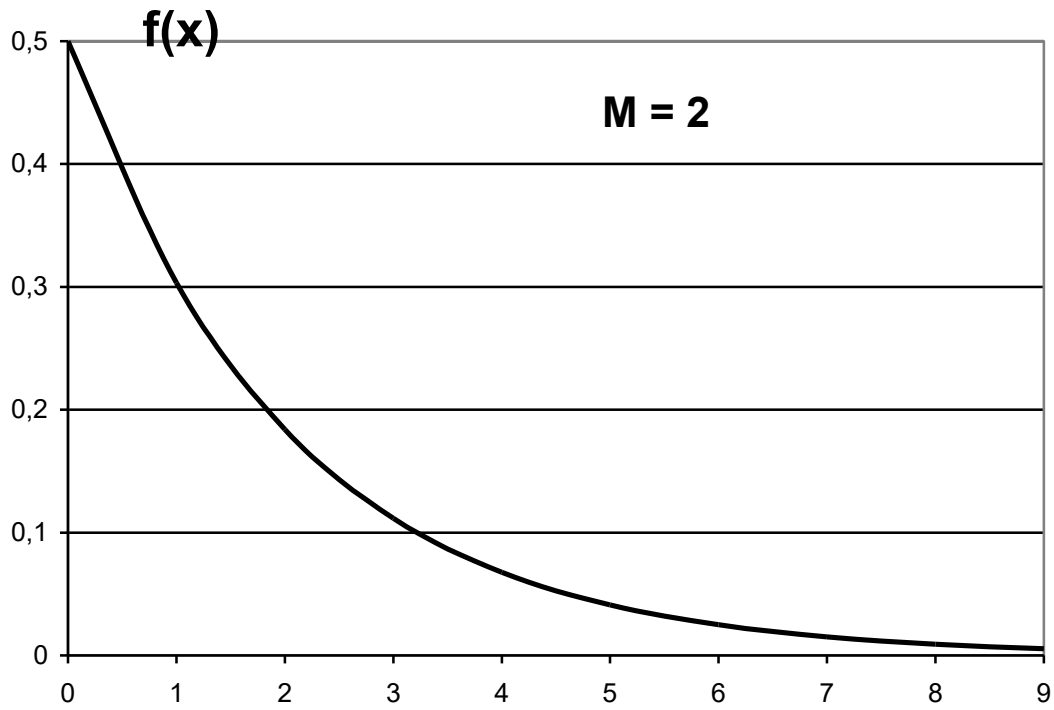


Fig. 5.3. The density of the exponential distribution at M=2, β=0,5

The distribution is defined when X>0, and the most likely values of the random variable are close to zero.

A characteristic feature of the exponential distribution is the constant values of its coefficient of variation **V**=1 and coefficient of asymmetry **A**=2.

The final decision on the possibility of applying the selected distribution law is made based on the results of checking its consistency with experimental data.

For this, special statistical consistency criteria are used, the most common of which is **the Pearson test**.

The Pearson test statistic is calculated using the formula

$$\chi^2 = N \sum_{j=1}^{L} \frac{\left(P_j - P_{jt}\right)^2}{P_{jt}}\ , \tag{5.16}$$

where **L** – the number of intervals in the histogram;

N – the size of the sample on which the distribution histogram is constructed;

$\mathbf{P_j}$ – the empirical probability of a random variable falling into the j-th interval, determined by the distribution histogram;

$\mathbf{P_{jt} = F(C_j) - F(C_{j-1})}$ – the theoretical probability of a random variable falling into the j-th interval, determined according to the chosen distribution law.

The sample value of statistics χ^2 calculated by formula (5.16) is compared with the critical value $\chi^2_{cr}(\alpha, k)$ determined by the Pearson distribution table depending on the level of significance α and the number of degrees of freedom **k**.

The level of significance α sets the probability of rejecting the correct hypothesis (recognizing the theoretical distribution that is actually consistent with experimental data as inappropriate).

In statistical studies, the level of significance α=0.05 is often accepted.

The number of degrees of freedom **k** is equal to the number of intervals in the distribution histogram **L**, reduced by the number of parameters of the selected theoretical distribution law and one more.

For Gumbel and Gauss distributions **k=L-3**; for the exponential distribution **k=L-2**.

If $\chi^2 \le \chi^2_{cr}$, the chosen distribution law does not contradict the experimental data and can be used for the probabilistic description of the studied random variable.

When $\chi^2 > \chi^2_{cr}$ for the approximation of experimental data, a distribution law of a different type should be chosen.

*In the above-considered **example** of statistical processing of time spent on course work, statistical characteristics were calculated and a distribution histogram was constructed, which is shown in Fig. 5.2.*

Shown in fig. 5.2 the graph of the density of the normal distribution quite accurately reflects the nature of the histogram.

The obvious dependence of time consumption on a large number of influencing factors also suggests the possibility of using a normal distribution for the probabilistic description of the investigated random variable.

The check of the consistency of the normal distribution law with the experimental data is performed in the table. 5.3.

For each of the six intervals of the histogram in the columns of the table, the experimental probabilities of hitting the interval P_j, the normalized values of t according to the formula (5.11), the value of the normal distribution function $F_j(t)$ for the end of the interval according to the table of normal distribution, the theoretical probability of hitting the interval P_{jt}, components of the Pearson criterion according to formula (5.16).

Table 5.3

An example of checking the consistency of the normal distribution law with experimental data

Interval number ***J***	*End of interval* C_j	P_j	$t = \frac{(x - M)}{S}$	$F_j(t)$	P_{jt}	χ^2
	12		*-1,89*	*0,0294*		
1	*15*	*0,10*	*-1,26*	*0,1038*	*0,0744*	*0,176*
2	*18*	*0,15*	*-0,62*	*0,2676*	*0,1638*	*0,023*
3	*21*	*0,25*	*0,01*	*0,5040*	*0,2364*	*0,016*
4	*24*	*0,20*	*0,64*	*0,7389*	*0,2349*	*0,104*
5	*27*	*0,15*	*1,28*	*0,8997*	*0,1608*	*0,015*
6	*33*	*0,15*	*2,55*	*0,9946*	*0,0949*	*0,640*
Total:		*1,00*			*0,9652*	*0,974*

The sum of the last column is equal to the Pearson test statistic $\chi^2=0.974$.

According to the Pearson distribution table for the level of significance $\alpha=0.05$ and the number of degrees of freedom k=6–3=3, the critical value of the criterion is $\chi^2_{cr}=7,8$.

Because $\chi^2=0,974<\chi^2_{cr}=7,8$, we conclude that the normal distribution does not contradict experimental data and can be used for a probabilistic description of time spent on course work.

LECTURE 6
Algorithm of scientific research process. The final stage of the research process. Construction of linear and non-linear empirical dependencies

The law of the distribution of a random variable allows solving a number of practically useful tasks, one of which is **estimating the probability of a random variable X** falling into a given interval **[a, b]** through a known distribution function **F(x)** or probability density **f(x)**

$$\mathbf{P\{a \le X < b\} = F(b) - F(a) = \int_a^b f(x)\,dx}\,. \qquad (6.1)$$

In practice, there are often cases when it is necessary to determine the probability of a random variable exceeding the set one-sided limit. Considering the opposite lower or upper limit of the interval **[a, b]** mentioned above to be infinite, it is easy to obtain from the general formula (6.1):

$$\mathbf{P\{X < b\} = F(b) = \int_{-\infty}^{b} f(x)\,dx}\ , \qquad (6.2)$$

$$\mathbf{P\{X > a\} = 1 - F(a) = \int_{a}^{+\infty} f(x)\,dx}\ . \qquad (6.3)$$

The general formulas (6.1) – (6.3) are derived from the definition of the distribution function (5.4) and dependencies (5.6).

By substituting specific expressions of the distribution function **F(x)** to them, you can obtain working formulas for the Gumbel distribution

$$\mathbf{P\{X < b\} = \exp\left[-\exp\left(\frac{\alpha - b}{\beta}\right)\right]}\ ; \quad \mathbf{P\{X > a\} = 1 - \exp\left[-\exp\left(\frac{\alpha - a}{\beta}\right)\right]}\ . \qquad (6.4)$$

as well as for the exponential distribution

$$\mathbf{P\{X < b\} = 1 - e^{-\beta b}}\ ; \qquad \mathbf{P\{X > a\} = e^{-\beta a}}\ . \qquad (6.5)$$

For a normal distribution function that does not have an analytical expression, the probability of a random variable exceeding the lower or upper limit is equal to

$$\mathbf{P\{X < b\} = F(b)}\ ; \qquad \mathbf{P\{X > a\} = 1 - F(a)}\ , \qquad (6.6)$$

where **F(a)** and **F(b)** – the value of the normal distribution function, determined from the table via the normalized argument (11).

No less important for practice is the inverse problem, which is often called **the problem of normalizing the calculated values of experimental parameters of technical objects or natural phenomena**.

The limit (maximum or minimum) value of the studied parameter, the probability of which can be considered quite small, is usually considered to be calculated. The probability of the opposite event, that is, the preservation of the parameter within the desired limits, is called **the assurance of the calculated value**.

So, for example, the lower limit of compressive strength with a guarantee of 0.95 is considered the strength class of concrete.

This means that the strength of 95% of the tested samples exceeds the value of the concrete class, and the strength of 5% of the samples may deviate from it in a dangerous, smaller way.

Normative and calculated values of loads on the structure, on the contrary, are assumed to be equal to the upper limit of the load with a security close to unity.

By substituting the exponential distribution function (5.15) into (6.4) and prologarithming the resulting expression, we determine the upper bound of the random variable with assurance **F**

$$\mathbf{X_{max} = -\ln(1-F)/\beta} \ . \qquad (6.7)$$

Substitution of the Gumbel distribution function (5.13) into (6.4) and double logarithmization of the resulting expression gives a formula for calculating the upper limit of a random variable with assurance **F**

$$\mathbf{X_{max} = \alpha - \beta \ \ln(-\ln F)} \ . \qquad (6.8)$$

The lower and upper bounds of a normally distributed random variable with assurance **F** are calculated by formulas

$$\mathbf{X_{min} = M - t\,S} \ ; \qquad \mathbf{X_{max} = M + t\,S} \ , \qquad (6.9)$$

where **M** and **S** – mathematical expectation and standard;

t – the normalized argument (5.11), determined according to the table for a given value of the normal distribution function.

*For the conditions of the **example** considered above, the curriculum allocates 24 hours for course work.*

The probability that the student will spend no more than 24 hours on the work is determined by formula (6.6).

The normalized value (5.11) of the random value of time expenditure is equal to $t = (x - M)/S = (24 - 20{,}95)/4{,}73 = 0{,}645$.

According to the normal distribution table, we determine F(0.645)=0.740. This means that 74% of students will be able to complete the task within the allotted time of 24 hours.

According to the requirements for higher education institutions of the IV level of accreditation, the absolute success rate should be at least 90%. The obtained result of 74% shows that the time norm of 24 hours is underestimated and does not correspond to the abilities of real students and the scope of the task.

For assurance of F=0,9 we will determine t=1,28 according to the table of normal distribution.

The corresponding rate of time is determined by formula (6.9) as the upper limit of the random amount of time spent in $X_{max} = M + t\,S = 20{,}95 + 1{,}28 \times 4{,}73 = 27{,}0$ *hours. Therefore, setting a time norm of 27 hours will ensure that 90% of students complete their coursework on time.*

Objects of research are often described by a set of several features that reflect different properties of the same object.

For example, each material sample has a certain average density, porosity, water absorption, compressive strength and bending strength, and other technical characteristics.

All these indicators are random variables, the values of which change from sample to sample, but at the same time they can be mutually dependent.

It is obvious that when porosity increases, water absorption increases, but the average density and strength limit of the material decrease.

Consider two random variables **X** and **Y** obtained as a result of a paired experiment.

If there is **a functional dependence** between them, then each specific value of **X** corresponds to a specific deterministic (precisely defined) value of **Y**.

Stochastic dependence consists in the fact that a specific value of **X** corresponds to a number of random values of **Y** that have a certain statistical spread.

If the set of possible values of the random variable **Y** changes when the values of **X** change, such random variables are called **dependent**.

So, for example, a student's body weight does not depend on the serial number in the group list, but depends on his age and height.

The results of a paired experiment can be represented graphically by plotting the value of the random variable **X** along one axis, and the value of **Y** along the other.

Each pair of data that characterizes the same object (the height and body weight of a certain person, the average density and strength limit of a sample of lightweight concrete, etc.) forms one point on the graph. According to such a graph, it is possible to roughly establish the presence and nature of the dependence between the analyzed values.

A statistical measure of the closeness of a linear (or close to linear) relationship between two random variables is the <u>correlation coefficient</u>, which is calculated by the formula

$$\mathbf{R_{xy} = \frac{1}{(N-1)\, S_x\, S_y} \sum_{i=1}^{N} (X_i - M_x)(Y_i - M_y)}, \qquad (6.10)$$

where **N** – the volume of each of the samples;

X_i and **Y_i** – corresponding elements of samples that reflect the results of a paired experiment for the same object;

M_X and **M_Y** – mathematical expectations scores (average values) of both samples;

S_X and **S_Y** – assessment standards of both samples.

During statistical processing of data in the EXCEL spreadsheet environment, it is convenient to calculate the correlation coefficient using the CORREL (array_X; array_Y) function.

By the value of the correlation coefficient, it is possible to judge the presence and nature of the relationship between random variables.

The correlation coefficient of independent random variables shown in Fig. 6.1 a, approaches zero.

The difference of the correlation coefficient from zero indicates the existence of a relationship between random variables, and its proximity in modulus to unity indicates the proximity of this relationship to a linear functional one.

When **$R_{XY}>0$** (Fig. 6.1 b), an increase in the value of **X** causes an increase in **Y**, and when **$R_{XY}<0$** (Fig. 6.1 c), on the contrary, larger values of **X** correspond to smaller values of **Y**.

If there is a fairly close relationship between the analyzed values (at values of the correlation coefficient $R_{XY}|>0,7$), the relationship between them can be described by a **linear regression equation** of the form

$$\mathbf{Y = A + B \times X}\ . \qquad (6.11)$$

Parameters **A**, **B** of the approximating linear function (6.11) are determined by the method of least squares, which ensures the minimum of the sum of squares of the deviations of the experimental values of **Y** from the approximating straight line (6.11).

For this, they are calculated using formulas

$$\mathbf{A = R_{XY}\, S_Y / S_X}\ ; \qquad \mathbf{B = M_Y - A\, M_X}\ , \qquad (6.12)$$

all the notations of which correspond to the formula (6.10).

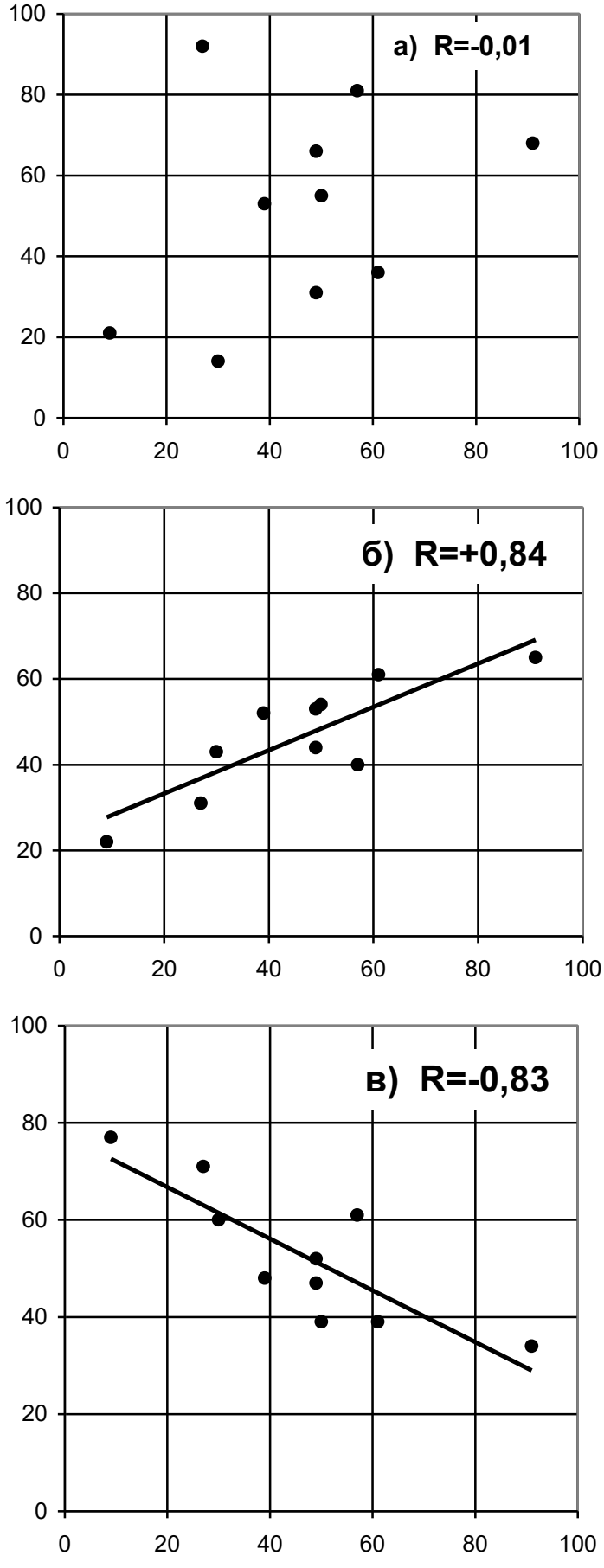


Fig. 6.1. Examples of dependencies between random variables

When using the EXCEL spreadsheet, the parameters of the linear regression equation (6.11) can be directly calculated using the formulas (6.12) or obtained on the constructed "point" type diagram by executing the "insert trend line" command.

From fig. 6.1b and 6.1c show that the approximating straight lines (6.11) describe experimental dependencies "on average".

The real experimental values of **Y** randomly deviate from the approximating straight line.

The value of the spread decreases to zero when the modulus of the correlation coefficient increases to unity, which corresponds to the transformation of the stochastic dependence into a functional one.

Dependencies between the properties of the research objects, obtained through paired experiments, may have a non-linear nature.

Approximation of such dependencies is performed by the method of least squares using various analytical functions.

When choosing the type of approximating function, the accuracy of approximation, asymptotic behavior, and convenience of further use of the approximating function should be taken into account.

A fairly universal and easy-to-use function, which is often used to approximate various dependencies, is an algebraic polynomial of the form

$$\mathbf{Y = A_0 + A_1 X + A_2 X^2 + ... + A_K X^K} \ . \qquad (6.13)$$

A significant number of extremums (one less than the degree of the polynomial **K**) determines the flexibility of the obtained curve; therefore, in practice, it is rarely necessary to use polynomials higher than 5-6 degree.

The selection of parameters $\mathbf{A_0 \ldots A_K}$ of the polynomial (6.13) is implemented in many application programs, including in the text processor EXCEL using the operation "insert trend line" in the constructed diagram of the "point" type.

The main disadvantage of the algebraic polynomial is the unpredictability of its asymptotic behavior, which does not allow the use of the function (6.13) outside the range of changes of experimental points used for approximation.

In the practice of approximating empirical nonlinear dependencies, a family of two-parameter functions is often used, which can be reduced to linear ones by means of certain transformations.

These functions have simple analytical expressions and well-defined asymptotic behavior and allow describing dependencies of various nature, which makes them convenient for practical use.

Some of the well-tested functions of nonlinear empirical dependencies are listed in the table. 6.1.

Table 6.1

Typical functions of nonlinear empirical dependencies

Functions		Scope limitation	Linearizing transformations		Reverse transformations of parameters	
1	$Y = A + B/X$	$X \neq 0$	$x = 1/X$	$y = Y$	$A = a$	$B = b$
2	$Y = X/(A + B\,X)$	$Y \neq 0$	$x = X$	$y = X/Y$	$A = a$	$B = b$
3	$Y = A\,e^{B\,X}$	$Y > 0$	$x = X$	$y = \ln(Y)$	$A = e^a$	$B = b$
4	$Y = A + B\ln(X)$	$X > 0$	$x = \ln(X)$	$y = Y$	$A = a$	$B = b$
5	$Y = A\,X^B$	$X > 0;\ Y > 0$	$x = \ln(X)$	$y = \ln(Y)$	$A = e^a$	$B = b$
6	$Y = A + B\,X^K$	$X > 0$ at $K < 1$	$x = X^K$	$y = Y$	$A = a$	$B = b$

Converting the experimental values of X and Y according to the table. 6.1 formulas, the specified functions can be reduced to a linear form $y = a + b\,x$ similar to (6.11).

The linearity of the transformed graph indicates a successful choice of the type of approximating function.

The parameters **a, b** of the transformed linearized function are calculated by formulas (6.12), as is done in the case of linear regression (6.11).

The parameters **A, B** of the nonlinear approximating function are calculated by the inverse transformation of the parameters given in the last columns of the same table.

Most of the indicated nonlinear approximations of functions can be selected using the EXCEL spreadsheet processor by executing the "insert trend line" command on the built-up "point" type diagram.

To approximate non-linear dependencies, it is also possible to use functions of an arbitrary type, chosen on the basis of an analysis of the characteristics of the behavior of the investigated phenomenon.

The parameters of such functions are calculated according to the method of least squares by numerically minimizing the sum of the squares of the deviations of the experimental points from the approximating function.

When using the EXCEL table processor, you should implement the calculation of the squares of deviations and their sum at the initial values of the parameters specified in certain cells of the spreadsheet, and then use the "solution search" item of the "service" menu.

The dependence of one variable on **K** arguments is approximated in the same way: $Y = f(X_1, X_2, \ldots X_K)$.

The type of approximating function is chosen based on experience and analysis of the phenomenon under study, and its parameters are calculated by minimizing the sum of squared deviations from the experimental points.

LECTURE 7
Basic terms and concepts of information support of the research process. Types of scientific documents, scope of their creation and use. Informational aspects of scientific research. Information support of the research process

The topic, purpose and tasks of scientific research work (dissertation, master's thesis, scientific and technical report, etc.) are formulated on the basis of the analysis of scientific achievements and practical experience in the selected field of science, engineering and technology.

The results of scientific research are usually published in the following sources:

- regulatory documents (standards, design norms, guides to them, etc.);
- handbooks, textbooks, training aids;
- monographs and brochures;
- dissertations and dissertation abstracts;
- articles in magazines and collections of scientific works;
- collections of works, materials and theses of scientific conferences and seminars;
- abstract bibliographic editions, information sheets;
- oral information at scientific conferences, symposia, seminars;
- Internet.

The search for the necessary information can be conducted rationally in the following ways:

- with the help of automated search systems (Internet and some computerized libraries);
- search by catalogs in the library (alphabetical, systematic, subject, journal articles, translations);
- retrospective search for references in literary sources to other, earlier sources;
- familiarization with magazines, collections of articles, theses and theses of conferences on related topics;
- systematic review of periodical and bibliographic publications.

In the process of working with literature, you should keep a card file of all studied sources with their complete bibliographic data, short annotations and notes on the content.

Sources that do not contain useful information should be included in the card index, making notes about their content. This will allow you not to return to their study in the future, and will also facilitate the search for information on related issues.

Sources containing useful information are summarized, partially or completely copied. Information should also be systematized by topic, which will simplify its analysis and generalization.

When summarizing literature data, it is important not only to outline the content of the studied publications, but also to analyze them from the point of view of their usefulness for the development of the chosen topic, the possibility of using the results in one's own research.

An objective comparative analysis will make it possible not only to assess the contribution of predecessors to the development of the chosen scientific direction, but also to build a kind of "launch pad" for starting one's own research. The analysis of literature ends with the writing of the text of the analysis of literary sources, which usually becomes the first section of the scientific research work (dissertation, master's thesis, scientific and technical report, etc.).

Scientific publications are prepared and published for the purpose of informing about work, confirming priority, discussing ideas and research results. Despite the different volume (from abstracts of a report on 1-2 pages to a monograph with a volume of several hundred pages), the structure, style and design of scientific publications generally remain close to the structure of a scientific and technical report.

We will give a brief description of the main types of scientific publications.

Theses have a volume of 1-3 pages, on which you can briefly convey the content of the report at the scientific conference, outline a certain narrow question, inform about the nature of the completed or started research and thus mark your priority in solving this scientific problem.

Theses are usually written in a "telegraphic" style, without illustrations and a list of references.

An article in a scientific journal or collection has a volume of 3-10 pages and is usually devoted to a detailed coverage of a specific issue, but review articles are also published.

According to the requirements of the HAC of Ukraine, a scientific article must contain the following components: statement of the problem and its connection with scientific or practical tasks, analysis of the latest research and publications, formulation of goals and objectives, presentation of research methodology and results with their justification, conclusions and prospects for further of research

The presentation of the material is illustrated with formulas, tables and figures, at the end of the article there is a list of used sources.

The monograph has a volume of several hundred pages, on which a wide range of scientific issues are presented with a review of the literature, a description of the methodology of the performed research, a presentation of factual data and their detailed analysis, and justification of scientific statements and conclusions.

The text of the monograph consists of chapters and subsections, contains formulas, tables and illustrations, appendices with factual data, etc.

A brochure usually has a volume of 48 pages, and its structure and design are similar to a monograph.

The style of scientific publications usually corresponds to the informative and evidential style of writing a scientific report, although it can be more concise.

Please note that reference books, study guides and textbooks should not be considered purely scientific publications, and therefore they are written in a slightly different style. In these editions, the informativeness and consistency of the presentation of the material come to the fore.

Scientific publications of all types can be individual or written by a team of authors.

If necessary, in the introduction or in the content of the monograph, specific authors who wrote certain chapters are indicated.

Scientific publications are **designed** according to the general rules outlined in the previous question, but in order to ensure stylistic unity, the editorial boards of journals and anthologies usually specify these rules (fonts, text formatting, illustration design, etc.).

Along with the printed text, editors usually require to provide electronic versions of publications, which provides the possibility of computer editing and layout and significantly speeds up the publication.

LECTURE 8
General requirements and rules for writing scientific papers. Peer review of research works

The execution of scientific work is completed by the design of the obtained results in the form of a scientific and technical report, dissertation, master's thesis, scientific publication or regulatory and technical document (standards, design norms, guides to norms, recommendations, etc.), etc.

All these documents are drawn up according to fairly close rules established by DSTU 3008-95 Documentation. Reports in the field of science and technology. The structure and rules of registration, as well as in the "Basic requirements for dissertations and dissertation abstracts".

A scientific and technical report (master's thesis, dissertation, etc.) should give a complete picture of the tasks, prerequisites, methodology and results of the performed research.

Presentation of the material should be logically structured, informative, concise and easy to understand.

The report consists of the following structural parts:

- **content;**
- **annotation;**
- **introduction;**
- **sections and subsections (paragraphs or clauses and subsections);**
- **conclusions;**
- **references;**
- **applications.**

The text of each section, appendix and other structural parts of the explanatory note begins on a new page; the texts of the subsections are placed one after the other on the current page.

The text of the report (master's theses, dissertations, etc.) is printed on one side of a sheet of white paper in A4 format with standard field sizes and, if necessary, bound together.

As a rule, personal computers with text and table processors and graphics programs are used to prepare reports, which allow you to accurately prepare text with tables, formulas, and illustrations.

Numbering. Pages, sections, subsections, figures, tables and formulas are numbered with Arabic numerals.

Chapter numbers of the main body of the text are placed after the word "Chapter" (for example, Chapter 1), after which the chapter heading is printed on a new line.

Subsections (paragraphs or clauses) are numbered within each section. The number of a subdivision (paragraph or item) consists of the number of the section and the serial number of the subdivision (paragraph or item), between which a dot is placed, for example 1.2. After the subsection number, its title is printed in the same line.

Leave two blank lines between the title of the section (paragraph or item) and the text.

The sub-item number consists of the number of the section, the item and the sub-item itself, for example 1.2.2.

Do not leave blank periods between the name of the subsection and the text.

Appendices are marked with letters of the Ukrainian alphabet, for example: "Appendix A". Each appendix starts on a new page and must have a title.

Structural parts of the explanatory note, such as the content, introduction, conclusions, list of used sources, do not have a serial number.

Tables, illustrations and formulas are numbered within a chapter or appendix. Each number consists of a chapter number or appendix letter and the number of a table, figure or formula, between which a dot is placed.

For references in the text of the work, table numbers are indicated after the word "table"; figure numbers - after the word "figure".

Formula numbers are given in round brackets.

Example:

Table 2.3;

Figure 2.3;

formula (2.3), –

respectively, the third table of chapter 2, the third figure of chapter 2, the third formula of chapter 2.

Similarly for applications:

Table B.2;

formula (B.3), –

the second table and the third formula of Appendix B.

In addition to the number, each figure and table should have a title that reveals their content.

Tables are used to present and organize digital and textual data.

Tables should be built in such a way that they facilitate the search and comparative analysis of the given data, confirm the regularities and considerations expressed in the text of the work.

The upper part (head) of the table contains the headings of the graphs, which should be meaningful and concise.

Each table should have a name that is printed above it symmetrically to the text.

The table number is printed above its name on the right side of the page.

Each table must be mentioned in the text of the report. This can be a simple reference such as "Test results are shown in Table 3.2" or a thorough analysis of the data in the table that takes up several paragraphs of text.

Illustrations are used to explain the research methodology, visual display of the revealed regularities, concise presentation of qualitative information, substantiation of the reliability of the research results.

Illustrations can be: dependency graphs, diagrams, histograms, nomograms, drawings, diagrams, sketches, photographs, etc.

Under each illustration, a signature containing the word "Fig.", serial number, meaningful name of the illustration, and an explanation (legend) explaining the details is made.

Each illustration should correspond to the logic of the presentation of the material, be mentioned and analyzed in the text of the report.

References to illustrations are given in the form of expressions like: "Figure 2.3 shows...".

Illustrations are usually placed immediately after the text where they are mentioned for the first time, or on the next page.

Formulas describe mathematical relationships, chemical reactions, etc.

The formula is placed in a separate line, at the end of which a number in round brackets is placed close to the right margin of the page.

Formulas are numbered within each section in order to refer to them in the text of the work.

To save space, several short, similar formulas can be submitted in one line under a common number.

Directly below the formula, printed on a separate line, are explanations of the meanings of the symbols and numerical coefficients in the order in which they appear in the formula.

The values of each symbol and numeric coefficient are given on a new line, and the first line begins with the word "where" without a colon.

Explanations of all or individual symbols can also be directly included in the text before the formula.

Punctuation marks are placed at the end of the formulas and in the text in front of them in accordance with the rules of punctuation, considering the formula as an element of the sentence.

Notes can contain references and explanations to tables or text and are placed, respectively, below the table or below the text, at the bottom of the page.

Several notes are numbered consecutively within one page. Texts of notes can be highlighted in font, for example, italics.

References to tables, illustrations, formulas in the text of the report are made by their serial numbers, for example: "...in table 3.2"; "... in Figure 2.3",

"... in formula (2.1)".

References to literary sources are made by the serial number in the list of sources used, highlighted in square brackets, for example: "... in works [22]; [34–37]...".

When using data from sources that have a large number of pages, it is advisable to indicate the page number, table, illustration or formula of this source, for example:

"... in table 6.4 of the monograph [33]";

"... according to formula (4.6) from [33]".

Citations can be given for the purpose of detailed analysis of the printed work.

The quoted text is given in quotation marks and reproduced exactly according to the original.

The omission of a part of the author's text is allowed, if it does not distort the content of the quote, and is indicated by three dots, which are placed at the beginning, in the middle or at the end of the quote.

Each quote must be accompanied by a reference to the source, for example: "... as the author claims [28]," "the text of the quote."

The list of used sources serves to refer to the authors and sources from which other information is borrowed.

Bibliographic descriptions of sources are compiled in accordance with the current standards of library and publishing business and are most often placed in alphabetical order of the surnames of the first authors and titles of works.

At the same time, usually, in the list of used sources, works published in Ukrainian or Russian languages are presented first, and then in English.

However, it is possible to compile a list of used sources in the sequence in which these sources are first referenced in the text of the dissertation (master's thesis, scientific and technical report, etc.).

By the way, all sources contained in the list of used sources must be referenced in the text of the work.

Let us consider several typical examples of bibliographic descriptions of literary sources published in the Ukrainian language:

- **Norms:**

ДСТУ Б В.2.1-4-96. Ґрунти. Методи лабораторного визначення характеристик міцності і деформованості / Державний комітет України у справах містобудування та архітектури. – К.: МНТКС, 1997. – 101 с.

ТР 31174865.001:2016. Технологічний регламент на буріння похило-скерованих і горизонтальних свердловин. – Полтава: ТОВ «НТП «Бурова техніка». – 2016. – 67 с.

• Book (monograph):

One author

Бойко В.С. Підземний ремонт свердловин / В.С. Бойко. – Івано-Франківськ: ІФНТУНГ, 2009. – 587 с.

Вадецкий О.В. Бурение нефтяных и газових скважин / О.В. Вадецкий. – М.: «Недра», 2003 – 352 с.

Two or three authors

Карп І.М. Стан і перспективи розвитку нафтогазового комплексу України / І.М. Карп, Д.О. Єгер, Ю.С. Зарубін. – К.: «Наукова думка», 2006. – 309 с.

Рудий М.І. Кислотне діяння на нафтогазовий пласт: у 2 кн. / М.І. Рудий, С.М. Рудий, С.В. Наслєдніков. – Івано-Франківськ: «Галицька друкарня плюс». – Кн.1. – 2011. – 482 с.; Кн.2. – 2011. – 576 с.

Four or more authors

Інтенсифікація припливу вуглеводнів у свердловину / Кочмар Ю.Д., Світлицький В.М., Синюк Б.Б., Яремійчук Р.С. – Львів: «Центр Європи», 2005. – 414 с.

Технологія і техніка буріння / В.С. Войтенко, В.Г. Вітрик, Р.С. Яремійчук, Я.С. Яремійчук. – Львів: Центр Європи, 2012. – 708 с.

• Book (textbook, manual, lecture notes, encyclopedia, reference book, etc.):

One author

Колісніченко Е.В. Бурові промивальні рідини: конспект лекцій / Е.В. Колісніченко. – Суми: СумДУ, 2013. – 76 с.

Two or three authors

Коцкулич Я.С. Закінчування свердловин: підручник / Я.С.Коцкулич, О.В. Тищенко. – К.: Інтерпрес ЛТД, 2009. – 366 с.

Шарафутдинов З.З. Буровые и тампонажные растворы. Теория и практика: справочник / З.З. Шарафутдинов, Ф.А. Чегодаев, Р.З. Шарафутдинова. – СПб.: ПроФЄВсионал, 2007. – 416 с.

Four or more authors

Современные составы буровых промывочных жидкостей: пособие / В.П. Овчинников, Н.А. Аксенова, Т.В. Грошева, О.В. Рожкова. – Тюмень: ТГНГУ, 2013. – 156 с.

- **Journal article:**

One author

Серженьга О.В. Вплив фільтрату бурового розчину та характеру насичення пластів на зміну параметрів зони проникнення / О.В. Серженьга // Розвідка та розробка нафтових і газових родовищ. – 2004. – № 4. – С. 40 – 47.

Two or three authors

Бейзик О.С. Буровий розчин для якісного розкриття продуктивних горизонтів / О.С. Бейзик, М.І. Оринчак // Розвідка та розробка нафтових і газових родовищ. – 2009. – №1(30). – С. 88 – 92.

Гошовський С.В. Ефективність сучасних технологій вторинного розкриття продуктивних горизонтів і шляхи її підвищення / С.В. Гошовський, Ю.І. Войтенко, П.О. Сорокін // Нафтова і газова промисловість. – 2013. – №2. – С. 12 – 15.

Світлицький В.М. Сучасні проблеми розкриття та збереження продуктивних характеристик пластів / В.М. Світлицький, О.О. Іванків, Є.В. Вішнікін // Нафтова і газова промисловість. – 2006. – №6. – С. 16 – 18.

Four or more authors

До оцінки первинного розкриття продуктивних горизонтів на родовищах України / М.А. Мислюк, І.М. Ковбасюк, В.М. Стасенко, М.В. Гунда // Нафтова і газова промисловість. – 2005. – №6. – С. 17 – 19.

До питання визначення відкритої пористості порід за допомогою газоволюметричного методу / М.Ю. Нестеренко, Я.А. Пилип, В.В. Іванов, Ю.М. Віхоть // Нафтова і газова промисловість. – 2011. – №2. – С. 17 – 20.

- **An article in a collection of scientific works or conference materials:**

One author

Рябоконь С.А. Жидкости глушения для ремонта скважин и их влияние на коллекторские свойства пласта // Серия: Нефтепромысловое дело. – М.: ВНИИЭгазпром, 1985. Вып.13. – С. 8 – 25.

Two or three authors

Андрусяк А.М. Удосконалення рецептур інгібованих бурових промивальних рідин для розкриття продуктивних пластів / А.М. Андрусяк, Є.Я. Коцкулич // Матер. Міжнар. наук.-техн. конф. «Нафтогазова енергетика». – Івано-Франківськ: ІФНТУНГ, 2013. – С. 519 – 521.

Григорян Н.Г. Эффективность вскрытия пластов стреляющими перфораторами на больших глубинах // Н.Г. Григорян, И.Н. Гайворонский, Н.С. Чихладзеидр // Тр. VI научно-техн. геофизической конф. – М.: Недра, 1970. – С. 16 – 19.

Four or more authors

Новітні методи розкриття та освоєння пластів з аномально низькими пластовими тисками / О.О.Іванків, В.М.Світлицький, М.М. Яворський, А.А.Писаренко // Науковий вісник ІФНТУНГ. – 2007. – №2(16). – С. 48 – 53.

- **Dissertation abstract:**

Богославець В.В. Вибір оптимальних рецептур бурових розчинів для розкриття нафтових пластів: автореф. дис. ... канд. техн. наук: 05.15.10 «Буріння свердловин» / В.В. Богославець. – Івано-Франківськ: ІФНТУНГ, 2014. – 19 с.

- **Dissertation:**

Зезекало И.Г. Химико-технологические проблемы повышения надежности добычи углеводородов путем применения аммиака и его производных: Дис… докт. техн. наук: 05.15.06 / И.Г. Зезекало. – К., 1996. – 353 с.

Клеттер В.Ю. Совершенствование буровых растворов для строительства скважин на акватории шельфа: дисс. ... канд. техн. наук: 25.00.15 / В.Ю. Клеттер. – Уфа, 2010. – 149 с.

- **A patent for an invention or a utility model:**

Патент на корис. модель 102206 U Україна, МПК E21B 43/00, C09K 8/02. Спосіб первинного розкриття продуктивних пластів з низьким пластовим тиском / Оринчак М.І., Чудик І.І., Бейзик О.С., Кирчей О.І.; заявник і патентовласник Івано-Франків. нац. техн. ун-т нафти і газу. - № 201502603 ; заявлено 23.03.15 ; опубл. 26.10.15, Бюл. № 20. – 3 с.

Патент № 20552A Україна, МКВ E21B 43/27. Спосіб кислотної обробки продуктивних пластів / заявник підприємство «Полтаванафтогаз» ВАТ «Укрнафта»: Рудий М.І., Манюк С.В., Козак К.Г., Кукуєв А.Г. – № 96010229: заявл. 19.01.96; опубл. 15.07.97.

- **Electronic resource:**

Бакулін Є.М. Екологічні аспекти виробництва та застосування змащувальних добавок до бурових рідин [Электр. ресурс] / Є.М. Бакулін // Науковий вісник ІФНТУНГ: Нафтогазова інженерія. – 2013. Вип. 1 – 69 с. Режим доступу до журн.: https://core.ac.uk/download/pdf/73907599.pdf.

Вдовиченко А.І. Сучасні вітчизняні емульсони для обробки бурових промивних рідин [Электр. ресурс] / А.І. Вдовиченко, І.І. Мартиненко, М.П. Єрмаков // Породоразрушающий и металлообрабатывающий инструмент – техника и технология его изготовления и применения. Вип. 21 – 82 с. Режим доступу до журн.: http://dspace.nbuv.gov.ua/bitstream/handle/123456789/144404/12-Vdovychenko.pdf?sequence=1.

Кунцяк Я.В. Експериментальні та промислові дослідження і прогнозування стійкості стовбурів горизонтальних свердловин у нестійких породах [Электр. ресурс] / Я.В. Кунцяк, Р.Я. Кунцяк // Розвідка та розробка нафтових і газових родовищ: Дослідження та методи аналізу. – 2011. – Вип. 1 – 62 с.

Петров Н.А. Смазочные добавки для буровых промывочных жидкостей Западной Сибири [Электронный ресурс] / Петров Н.А., Давыдова И.Н. // Нефтегазовое дело: Геология, геофизика, бурение. – 2014, т. 12, №2 – 54 с. Режим доступу до журн.: HTTP://NGDELO.RU/FILES/OLD_NGDELO/2014/2/NGDELO-2-2014-P54-63.PDF

The design of literary sources published in English is generally similar to the design of literary sources published in Ukrainian or Russian.

Let's consider several typical examples of bibliographic descriptions of literary sources published in English.

• Book (monograph):

Briaud J.-L. Geotechnical Engineering: Unsaturated and Saturated Soils / J.-L. Briaud. Wiley. – 2013. – 1024 p.

Manjriker A. Foundation Engineering / A. Manjriker, I. Gunarante. – New York: Taylor and Francis, 2006. – 608 p.

- **Journal article:**

Churcher P.L. Properly designed underbalanced drilling fluids can limit formation damage / P.L. Churcher // Oil and Gas J. – 1996, Vol. 94, №18. – P. 50 – 56.

- **An article in a collection of scientific papers or conference materials:**

Chau K. Numerical Methods / K. Chau // Proc. of the 18th Intern. Conf. on Soil Mechanics and Geotechnical Engineering. – Paris. – 2013. – P. 647 – 654.

Dmytrenko V. Selection of effective corrosion inhibitors for bischofite solutions and simulated medium of formation waters / V. Dmytrenko,

Yu. Vynnykov, I. Zezekalo // E3S Web of Conferences. Vol. 166, 06005 (2020). The Intern. Conf. on Sustainable Futures: Environmental, Technological, Social and Economic Matters (ICSF 2020). doi: https://doi.org/10.1051/e3sconf/202016606005.

The development of potassium cellulosic polymers and their contribution to the inhibition of hydratable clays / S. Palumbo, D. Giacco, M. Ferrari, P. Pirovano // SPE JADC Drilling conf. – 1989. III. – №18477. – P. 149 – 152.

The appendices of the scientific and technical report (dissertation, master's thesis) are intended for the placement of supporting materials that may make it difficult to read the text of the report, but are necessary for a detailed study of research results.

The appendices usually state:

• intermediate mathematical proofs, formulas and calculations;

• descriptions of developed algorithms and computer programs;

• tables of auxiliary digital or other data;

• mass illustrations of the same type of auxiliary character;

• separate documents recommended for implementation (instructions, methods, technical conditions, technological maps);

• test protocols, acts and certificates on the implementation of research results, etc.;

• certificates of approval of research results, certificates of participation in conferences, etc.

The text of the appendix is drawn up in the same way as the text of the section of the explanatory note, but the numbers of tables, figures and formulas do not begin with a number - the number of the section, but with the letter that denotes the appendix.

A review is a publication in which a literary or scientific work is discussed and evaluated.

Regarding the review of the dissertation or master's thesis, it should usually contain the following components:

• Actuality of theme;

• Degree of substantiation of scientific provisions, conclusions and recommendations;

• Reliability and scientific novelty of the conducted research;

• Completeness of reflections of the main provisions of the dissertation in the published works;

• The identity of the abstract with the main provisions of the dissertation (this point is only for dissertation reviews);

• Analysis of the content of the dissertation (master's thesis);

- Remarks and questions about work;
- General evaluation of the work.

LECTURE 9
Peculiarities of the researcher's creative work. Basics of scientific organization of the research process

Scientific activity is a collective work related to issues of prestige, priority, intellectual property rights, and therefore ethical problems acquire great importance.

The main ethical principles of scientific activity are as follows:

• an objective approach to conducting research and highlighting the results, accuracy and completeness of their presentation, confirmation of new provisions by the results of experimental or theoretical research, provability of conclusions;

• respect for the opinion and scientific results of colleagues, in-depth study and objective analysis of the works of predecessors, objective evaluation of scientific statements and results regardless of their authorship;

• references to the works of colleagues, used ideas and results, use of experimental data with the permission of the author, inadmissibility of plagiarism;

• principledness in defending one's own scientific views and admitting their fallacy, if it is scientifically proven;

• clear self-assessment of one's own role in collective works, relations between co-authors, manager and performers.

Intellectual property rights to scientific results and developments are regulated by the legislation of Ukraine and other countries of the world. Among the laws of Ukraine regulating the field of intellectual property, it is appropriate to highlight the following:

• **About property.** The concept of intellectual property is declared, subjects (citizens, legal entities, the state) and objects (results of scientific research, works of science, literature, art, inventions) are defined.

• **About copyright and related rights.** The author is a natural person whose creative work created the work. The concepts of property and personal rights, the concept of related rights, the possibility of legal succession and alienation are defined, and other terms are explained. Property rights are valid for 50 years after the death of the last co-author, personal rights are valid for life. Lists of protected works (works of science, literature, art, architecture, oral works) and not protected by law are given. Cases of possible use of works without the author's consent have been established (single copies for personal use and without commercial purpose, news, educational process, quotes, illustrations).

• **On the protection of rights to inventions and utility models.** An invention is the result of a person's creative activity in any field of technology; a useful model is a practical implementation of the invention. Defined concepts of the object of the invention (product and method), conditions of patentability (novelty, industrial suitability, inventive step). The law protects the formula of the invention (patent for 20 years for the invention and for 5 years for the utility model), which is considered used in the implementation of all essential features. Formulated rights and the

procedure for obtaining a patent. Conditional cases of patent use that do not violate the rights of its owner (used before patenting, without commercial purpose, for scientific purpose, under extraordinary circumstances).

• **On the protection of rights to industrial designs.** An industrial sample is the result of a person's creative activity in the field of artistic construction (design). The object of protection is the shape, drawing, coloring that determine the appearance of an industrial product and are designed to meet aesthetic and ergonomic needs. Similar to an invention, a patent is issued for 10 years with the right to extend for 5 years.

• **On the protection of rights to signs for goods and services.** A trademark is a designation by which goods and services of one person differ from similar goods and services of other persons. The object of protection can be verbal, pictorial, three-dimensional and other designations or their combinations, made in any color or combination of colors. Official symbols (coats of arms, seals, emblems of international institutions) are not subject to protection, but they can be included in your mark. Signs without distinctiveness, misleading (distorted company name), commonly used symbols and terms (including for a given type of product or service), with elements of advertising (type, quality, price, place of sale, etc.) are also not protected. A certificate is issued for 10 years with the possibility of further extension every 10 years.

Creativity is the activity of a person that creates something qualitatively new and is distinguished by uniqueness, originality and socio-historical uniqueness.

Creativity is an extremely complex, informal process, which is characterized by manifestations of intuition and heuristics.

Heuristics is decision-making not according to a deterministic algorithm based on formal logic, but as a result of enlightenment, that is, a sudden understanding of a situation or problem.

Intuition is the ability to make informal decisions based on available information and previously acquired experience.

"Intuition is a quick decision that requires long-term preparation" (psychologist Teplov).

"Intuition is a reward for previously invested work" (Albert Einstein).

There is a whole range of assessments of creativity: from art to science or even craft. In fact, both logic and intuition are important in creativity.

This, in particular, is clearly visible from **the characteristic stages of the creative process**:

• understanding of the task (logic and intuition);

• collection of information and preparation for a decision (logic);

• carrying an idea (subconscious mind);

• insight and making a heuristic decision (intuition);

• verification and confirmation of the idea, final processing of the solution (logic).

According to the literature, an approximate **list of character traits that initiate creative abilities and form a creative personality** has been formulated:

• ability to see the problem;

• breadth of thinking, ability to generalize related problems and replace a group of concepts with one, integrity of perception;

• the ability to transfer experience, build associations, see analogies, connect previous experience with new problems;

• flexibility of thinking, ease of transition to new concepts and problems;

• ease of generating ideas;

• method of coding and perception of information;

• readiness of memory to remember and recall information in time;

• ability to predict;

• ability to formulate;

• ability to evaluate;

• ability to process details;

• concentration, persistence, efficiency.

Since all these traits can hardly be inherent in one person, scientific work is often carried out by creative teams composed of specialists who possess different sets of knowledge, skills and character traits.

To ensure the effective work of the creative team, the basic principles of its organization should be followed:

• adequate distribution of roles (manager, idea generator, erudite, opponent, executor) for solving this task by the forces of a certain team;

• conformity of formal and actual hierarchy;

• professional, psychological and moral compatibility of employees;

• scientific equality, right to criticism and error;

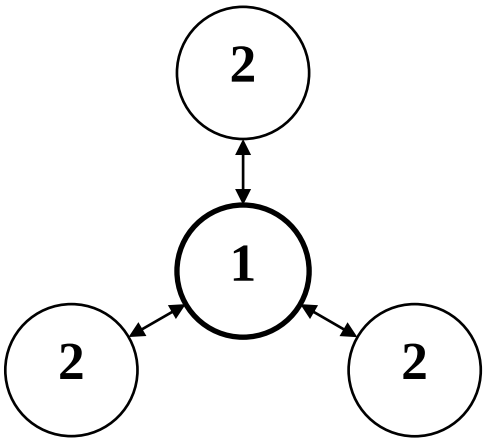
• discipline and clear organization of cooperation;

• continuous renewal, rejuvenation and development of the team.

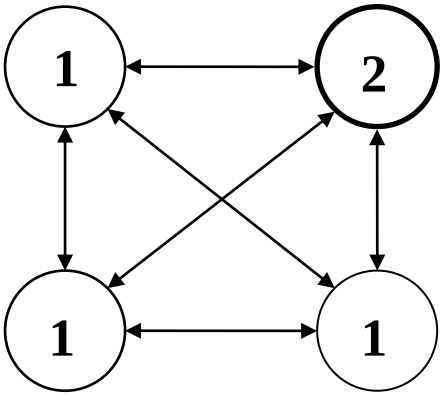
Depending on the assigned task, professional direction and relations between members of the creative team, different schemes of official communication and cooperation can be implemented: from complete closure to the manager (Fig. 9.1 a) to free communication (Fig. 9.1 b).

Often, intermediate options are implemented, which can change during the work. The manager's task: to submit and evaluate ideas, organize, provide and stimulate work.

At the same time, it is important to stimulate independence, initiative and responsibility in work, to educate the above-listed traits of a creative personality in subordinates.



a



b

Fig. 9.1. Schemes of organizing the interaction of members of the creative team:
a – centralized interaction; b – free communication;
1 – manager; 2 – employees

Heuristics is a system of knowledge about the methodology and organization of creative thinking. Some elements of heuristics have been known since the time of Socrates, who guided people to their own solutions to problems by a system of questions and remarks (now it is the method of control questions).

Heuristic methods of finding solutions can be divided into: associative, modification, generalized-algorithmic and systematic search methods.

These methods are quite fully described in the literature. The essence of the most famous heuristic methods, which are widely used in solving inventive, scientific-technical and managerial problems, is briefly described below.

The method of focal objects is an associative method of finding solutions, which is implemented in the following order:

• the focal object is selected, which is in the "focus" of the researcher's attention, that is, the subject of the study;

• 3 – 5 random objects are selected, in no way related to the focal one, and lists of characteristic features (properties) of these objects are compiled;

• features of random objects are attributed to the focal object, the resulting combinations are developed on the basis of free associations and analyzed;

• received ideas are evaluated by experts and useful solutions to the given or related scientific and technical problems are selected from them.

The brainstorming method is also an associative method of finding solutions, the use of which is reduced to the following procedures:

• two working groups are formed: "idea generators" who will participate in the brainstorming session, and "experts" who will later evaluate the proposed solution options;

• a brainstorming session (meeting of a group of "idea generators") is held with mandatory observance of two principles: the proposed solutions are not discussed or criticized, but they can be developed and supplemented;

• at the beginning of the brainstorming session, the head of the "idea generators" group sets the task, gives the floor to the brainstorming participants and directs the discussion, during which a full recording of all speeches is conducted;

• after the end of the session, a group of "experts" analyzes all the presented proposals and selects the most promising ideas for further development.

Due to the relaxed atmosphere (no criticism) and efficiency (no discussion of ideas), dozens of new ideas are generated during a brainstorming session lasting up to an hour, some of which may be quite promising.

The day after the brainstorming session, written proposals for a possible solution can be accepted.

Experience shows that there are few such proposals, but they are more thoughtful and effective.

The task of reverse brainstorming is to criticize a known decision with the aim of rejecting it or confirming its legitimacy, finding shortcomings and problems that may arise in the process of its implementation.

The method of morphological analysis belongs to methods of systematic search for solutions and is reduced to performing the following operations:

• the research object is selected and the task is formulated;

• a list of morphological features is drawn up (technical characteristics, components, parameters, conditions of production and operation of the object);

• a list of possible values of each morphological feature is compiled;

• a set of possible solutions is formed through a complete search of all possible combinations of values of morphological features, the number of which can be quite large (equal to the product of the number of values of all features);

• the functional value of each of the obtained options is determined and the optimal solution or several prospective solutions are selected.

The most important elements of the method are the selection of a list of morphological features (all essential features should be covered without increasing the set of possible solutions to an unrealistic one for analysis) and a systematic, comprehensive evaluation of the solutions obtained. Among them there are well-known, technically impossible, absurd, but unexpected, new, effective solutions to the problem can be found.

The method of control questions is an example of a modification method of finding solutions. The researcher must answer a number of questions that force him to analyze the problem from all sides, stimulating the adoption of an informed decision. There are several sets of control questions formulated by experienced inventors and psychologists.

The purpose of all lists of control questions is to stimulate a comprehensive systematic analysis of the task and possible options for its solution.

LITERATURE

1. Білуха М.Т. Методологія наукових досліджень: підруч. / М.Т. Білуха. – К.: АБУ, 2009. – 480 с.

2. Возняк Л.С. Чисельні методи: Методичний посібник для студентів природничих спеціальностей / Л.С. Возняк, С.В. Шарин. – Івано-Франківськ: «Плай», 2001, – 64 с.

3. Ковальчук В.В. Основи наукових досліджень / В.В. Ковальчук, Л.М. Моїсєєв. – К.: Персонал, 2004. – 215 с.

4. Колесников О.В. Основи наукових досліджень. 2-ге вид. випр. та доп. Навч. посіб. / О.В. Колесников – К.: Центр учбової літератури, 2011. – 144 с.

5. Крушельницька О.В. Методологія і організація наукових досліджень: [наук. посіб.] / О.В. Крушельницька. – К.: Кондор, 2009. – 192 с.

6. Львовский Е.Н. Статистические методы построения эмпирических формул: учебное пособ. для вузов. – 2-е изд. / Е.Н. Львовский. – М.: Высш. Шк., 1988. – 239 с.

7. Макогон Ю.В., Пилипенко В.В. Основи наукових досліджень / Ю.В. Макогон. − Донецьк: Альфа-прес, 2007. − 144 с.

8. Пілюшенко В.Л. Наукове дослідження: організація, методологія, інформаційне забезпечення / В.Л. Пілюшенко, І.В. Шкрабак, Е.І. Славенко. – К.: Лібра, 2004. – 344 с.

9. Радченко С.Г,. Методология регрессионного анализа: Монография / С.Г. Радченко. – К.: «Корнийчук», 2011. – 376 с.

10. Романчиков В.І. Основи наукових досліджень / В.І. Романчиков. – К.: ЦУЛ, 2007. – 254 с.

11. Статистична обробка даних: монографія / В.П. Бабак, А.Я. Білецький, О.П. Приставка, П.О. Приставка. – К.: «МІВВЦ», 2001. – 388 с.

12. Шаповаленко В.А. Чисельне обчислення функцій, характеристик матриць і розв’язування нелінійних рівнянь та систем рівнянь: Навч. посібник / В.А. Шаповаленко, Л.М. Буката, О.Г. Трофименко. – Одеса: ВЦ ОНАЗ, 2010. – Ч.1. – 88 с.

13. Як підготувати й захистити дисертацію на здобуття наукового ступеня. Методичні поради // Автор-упорядник Л.А. Пономаренко. – К.: Редакція «Бюлетеня Вищої атестаційної комісії України», Вид-во «Толока», 2001. – 80 с.

DICTIONARY OF TERMS

Abstraction is a scientific method, according to which conditional separation from a number of non-essential properties, connections, relations of objects and the selection of individual sides of the object for research are carried out. It is carried out in stages: first, the properties of the object are studied and divided into essential and non-essential, then the object of research is replaced by another, which constitutes a simplified model that preserves the main thing in the complex. Types: identification (creation of new concepts by combining objects or phenomena, interconnected by properties, into a special class); isolation (selection of properties inextricably linked to objects); constructivism (separation from the uncertainty of the boundaries of real objects); assumptions about potential implementation.

An axiom is an initial statement, intuitively obvious or a priori true, which is accepted without proof as a basis in some theory and from which (or a set of) all other propositions of this theory are derived within the limits of the rules of derivation adopted in it.

Axiomatization is the process of building a scientific theory, in which some axiom statements, which are certain scientific knowledge, are accepted without further proof, and then used as starting points for obtaining new knowledge according to certain logical rules.

Analysis is a method of cognition, in which a practical or conditional dissection of the research object into its components is carried out in order to study individual parts as elements of a complex whole. This makes it possible to reveal the structure of the object, to separate the essential from the inessential, to reduce the complex to the simple. Analysis of the phenomenon in the process of development makes it possible to distinguish separate stages, contradictory trends, etc. in it. It is inseparably connected with synthesis - the reverse process of uniting parts, features, properties of the object determined by analysis into a single whole.

Analogy is a scientific method, by which a conclusion about an object or phenomenon is made on the basis of its similarity with others, already known. The usual scheme of inference by analogy: if object *A* is characterized by features *a, b, c, d, e*; and object *B* - features *b, c, d, e*; therefore, object *B* is likely to have characteristic a. Mandatory conditions for research by analogy:

- the analogy should be based on essential features and as many similar characteristics of the objects of comparison as possible;
- the connection of the characteristic about which a conclusion is made with the general characteristics found in the objects should be very close;
- analogy should not lead to the conclusion that the objects are similar in all features;

- a conclusion by analogy should be supplemented by a study of differences and evidence that these differences cannot serve as a basis for rejecting conclusions by analogy.

Annotation is the process of analytical and synthetic processing of a scientific document, which consists in compiling a concise description of the content and purpose of the document, its main topic and the purpose of the work performed. The result of this process is an abstract.

Bibliographic description is the process and result of analytical and synthetic processing of scientific documents, which consists in compiling a list of information about the document according to established rules, which make it possible to fully identify this document and find it among others for the purpose of using it in various types of works.

A brochure is a printed edition of 5 to 48 pages.

Measurement is a physical process of determining the numerical value of some value by comparing it with a standard.

Implementation of the results of scientific research - transfer to production or everyday practical activity of scientific products (reports, instructions, technical conditions, technical projects, temporary instructions etc.), which provides a technical and economic effect, in a form convenient for implementation (the SRW turns into a product only from the moment of its "consumption" by production).

The main function of science is the development of a knowledge system that contributes to the most rational organization of production relations and the use of production forces in the interests of all members of society. It is divided into a number of specific functions: cognitive - satisfaction of people's needs in learning about the laws of nature and society; cultural and educational - development of culture, humanization of education and formation of a new person; practical - improvement of production and the system of social relations.

A hypothesis is a system of inferences, scientific assumptions, with the help of which, on the basis of a number of facts, a conclusion is made about the existence of an object, connection or cause of a phenomenon, and this conclusion is not absolutely reliable. The need for a hypothesis arises in science when there is an unclear connection between phenomena, their cause, although many circumstances that precede or accompany it are known; when it is necessary to establish a picture of the past based on some characteristics of the present; on the basis of the past and the present, it is necessary to draw a conclusion about the future development of the phenomenon. The hypothesis has a probable character and requires verification and proof. After such verification, the hypothesis either becomes a scientific theory or is modified.

A hypothetical method is a scientific method of research based on a hypothesis - a scientific assumption that is put forward to explain a certain phenomenon and needs verification and theoretical justification in order to become a reliable scientific theory. They are used in the study of new phenomena that have no analogues.

Dissertation for obtaining an academic degree is a qualifying scientific work performed personally by the applicant in the form of a specially prepared manuscript. The dissertation contains scientifically based theoretical or experimental results, scientific propositions put forward by the author for public protection, is characterized by unity of content and testifies to the personal contribution of the recipient to science.

Proof is a procedure for establishing the truth of a hypothesis or other statement. Two methods are possible: the direct method, which consists in the fact that in the process of practical actions there is a comparison of some assumption with the actual state of the research object (in particular, experiment, measurement, observation, calculations, accounting, etc.); mediated, when the truth of a hypothesis or statement is proven by means of inferences based on already existing knowledge in the form of various laws and regulations, the truth of which has already been proven.

A doctoral dissertation is a qualifying scientific work in which scientific propositions are formulated and substantiated, characterized as a new direction in the relevant field of science, or a theoretical generalization and solution of a scientific problem of great national economic and socio-cultural significance is carried out.

A document is a material object containing fixed information for its preservation and use.

A printed document is a printed product that is a certain type of scientific document that has undergone editorial and publishing processing (books, magazines, brochures).

A scientific document is a medium in which scientific data or scientific and technical information is recorded with a mandatory reference to where, by whom and when it was created. Scientific documents are divided into primary ones, which contain the direct results of scientific research and development, new scientific data or a new understanding of known ideas and facts, and secondary ones - the results of analytical-synthetic and logical processing of one or more primary documents or information about them.

A handwritten document is an information carrier that has not undergone editorial and publishing processing and has not been issued by means of polygraphy (scientific and technical reports, accounting documents of economic activity, dissertations, etc.).

The economics of science is a branch of science that examines the interaction of science and production, creates prerequisites for the generalization of practical experience, its theoretical understanding and impact on production.

The economic efficiency of scientific research is the reduction of the costs of social and living labor for the production of products in the field where completed scientific research works and research and development developments are implemented.

An experiment is a scientific method of studying phenomena by actively influencing them by creating new conditions in accordance with the purpose of the study or by directing the course of the process in a new direction. Some experimental

conditions are isolated, others are excluded, others are strengthened, etc. If necessary, the parameters of the experiment can be changed in such a way as to investigate individual properties of the object, rather than their totality.

A collection of scientific papers is a printed scientific document containing a number of scientific materials by one or more authors.

The content of science is a set of intellectual assets of mankind, consisting of: theory as a system of knowledge, which is a form of social consciousness and achievements of human intelligence; social role in the practical use of recommendations for the production of goods, which is a vital necessity of people.

Knowledge is a higher level of information functioning in society, transformed and processed by a person in a special way, as a result of which information acquires essence and meaning, acquires a symbolic form or is presented in this form with the help of other knowledge already accumulated by mankind.

Idealization is a scientific method, which is based on the creation of certain abstract objects, which in principle cannot be realized in experiment and reality. Idealized objects are extreme cases of certain real objects, they act as means of their scientific analysis, the basis for building a theory of real objects (for example: a straight line, an ideal solution, an ideal gas, an absolute black body, etc.).

Induction is a research method in which a general conclusion about the characteristics of a set of elements is made on the basis of studying these characteristics of some part of the elements of this set, providing the possibility of transition from individual facts to general statements. In real knowledge, induction is always combined with deduction - a scientific method, according to which a conclusion about the characteristics of any element of a set is made on the basis of knowledge of the general characteristics of the entire set.

Informatics is a scientific discipline that studies the structure and general properties of scientific information, regularities of scientific communication processes, methods of presenting information; use of codes for effective transmission, storage and retrieval of information; computing machines and their software and mathematical support, etc. It has its own theory, which studies the subject regardless of its use, and an applied part aimed at the development of information services.

New information – information that reflects the novelty of the proposed solution or justifies the cause of the defects identified by the research. Information is relevant - information whose content corresponds to the information need, is contained in analogues, prototypes and concerns only that part of research objects where significant differences are found.

Information provision is the process of meeting the needs of specific users in information, based on the use of special methods and means of obtaining, processing, accumulating and issuing it in a user-friendly form.

The history of science is a branch of science, which is the accumulation of scientific knowledge that characterizes the development of both individual sciences and science as a whole in the historical aspect.

The historical method involves the study of the origin, formation and development of objects in a chronological sequence, as a result of which additional knowledge is created about the object of research in the process of its development.

Candidate's dissertation is a qualifying scientific work that contains:

- new scientifically based results that collectively solve a specific scientific task that is of significant importance for the specific direction of a separate field of science;
- new scientifically based theoretical or experimental results, which in aggregate are essential for the development of a certain direction of a separate field of science.

Categories are forms of awareness in the concepts of general ways of a person's attitude to the world, reflecting the most general and essential properties, laws of nature and society.

Classification of sciences - performs the functions of grouping scientific knowledge into certain systems, which contributes to the unification of science, its international relations and acceleration of the pace of development.

The book is a printed multi-page non-periodical work of more than 48 pages.

A complex problem is a set of scientific problems, theoretical and practical tasks, united by one scientific idea, a common goal.

Concretization is a scientific method, which consists in the study of objects or phenomena in all the qualitative versatility of their real existence. At the same time, the state of objects is investigated in connection with certain conditions of their existence and historical development.

The purpose of science is to describe, explain and predict the processes and phenomena of reality that are the subject of its study on the basis of the laws discovered by it; theoretical reflection of reality for the purpose of use in people's practical activities.

The purpose of scientific research is to determine a specific object and a comprehensive reliable study of its structure and characteristics in order to obtain and put into practice the results useful for humans.

Method – a way of researching phenomena, a planned approach to their study, a sequence of actions in conducting theoretical research or practical implementation of a phenomenon or process; in the most general sense - a method, a certain way of organized activity and a kind of tool for achieving a specific goal.

Methodology is a philosophical teaching about the methods of knowledge and transformation of reality, the use of worldview principles in the process of knowledge and practice; contains a set of cognitive tools, methods, and techniques used in a certain science, as well as a field of knowledge that studies the tools, prerequisites, and principles of organizing cognitive and practical-transformative human activity.

The language of science is a branch of science that studies a certain system of concepts with the help of which individual scientific knowledge is transformed into collective property.

Modeling is a scientific method consisting of theoretical and practical actions aimed at the development and use of models - images of real objects (processes) in material or ideal form, which reflect the essential properties of the objects (processes) being modeled, and replace them during the study. It is based on the method of analogy - the possibility of studying a real object through the study of a similar and more accessible one, namely a model.

A monograph is a printed non-periodical scientific document that presents the results of a comprehensive study of one problem or topic of TV, which belongs to one author or a small group of authors (collective monograph).

Educational publications are non-periodical publications containing systematized information of a scientific and applied nature, presented in a form convenient for teaching and learning.

Science is a dynamic system of knowledge that reveals new phenomena in society and nature for their use in practical human activities.

Scientific information - information that adequately reflects the phenomena and laws of nature, society and thinking and is used in socio-historical practice, obtained as a result of the activities of individual scientists and specialists or their collectives, processed and generalized by abstract and logical methods and recorded in a system of precise concepts, judgments, conclusions, theories, hypotheses.

The scientific organization of work in the research process is a system of measures aimed at improving the methods and conditions of intellectual work, and preserving the health of workers based on the latest achievements of science and technology, which ensure the greatest efficiency at the lowest costs of intellectual work. As a system, it consists of separate elements: organization of labor processes and workplaces, provision of favorable working conditions, organization of work for functional maintenance of workplaces, rationing and material stimulation, development of creative abilities of employees.

A scientific problem is a complex of theoretical and practical tasks, the need to solve which has arisen before society; reflecting the contradiction between the need for new knowledge and the known ways of obtaining it (global, national, regional, industry, etc.).

Scientific and scientific and technical expertise is the most detailed and objective method of evaluating scientific activity and its results, the purpose of which is research, verification, analysis of the scientific and technical level of the object of expertise and the preparation of substantiated conclusions for decision-making regarding such objects.

Scientific research is the study of phenomena and processes, the analysis of the influence of various factors on them, the study of the interaction between phenomena with the aim of obtaining convincingly proven and useful solutions for science and practice with the maximum effect.

A scientific question is a small scientific task related to a specific topic of research. Empirical tasks are aimed at the identification, accurate description, detailed study of various factors of experimental processes and phenomena. Theoretical tasks are aimed at identifying and studying the causes, connections,

dependencies that make it possible to establish the behavior of the object, determine its structure, characteristics based on the principles and methods of cognition developed by science.

The scientific research process is a clearly organized complex of actions aimed at obtaining new knowledge that reveals the essence of processes and phenomena in nature and society, for their use in the practical activities of people.

A scientific law is an internal essential and stable connection of phenomena and processes, which determines their orderly changes and makes it possible to reliably predict the course of these phenomena or processes. It exists objectively, independently of people's consciousness, as a reflection of the necessary essential, internal relations between the properties of things or phenomena or various trends in their development. A scientific law is not created by a person, but only revealed, revealed, formulated in such a way as to correspond to the realities of the objective world, to be an accurate reflection of them.

A scientific field is a separate science or complex of sciences within which research is conducted (technical, biological, economic, etc.), with possible further detailing. Structural units of the scientific direction are complex problems, topics, scientific questions.

Science is a branch of research that studies the regularities of the functioning and development of science, the structure and dynamics of scientific activity, the interaction of science with other social institutions and spheres of the material and spiritual life of society.

A review is the result of analytical and synthetic processing of scientific documents, which is a text containing synthesized information on some issue or a series of issues, extracted from a certain set of primary documents specially selected for this purpose, issued over a certain period of time. Reviews are distinguished: bibliographic; abstract, analytical.

A bibliographic review characterizes primary documents as sources of information that appeared over a certain period of time or are united by a certain common feature.

Referential review contains systematized data and facts and generalized information about the state of the issue without their critical assessment by the author of the review.

Analytical review is a comprehensive analysis of all information contained in the source primary documents, a reasoned assessment and reasonable recommendations for the use of this information.

The object of scientific research is a process or phenomenon to which the cognitive activity of the researcher is directed in order to learn its essence, the patterns of development and the possibilities of further use in practical activities.

Comparison is a cognitive technique that consists in comparing objects to determine the features of similarity or difference between them (or both together). Comparison is an important prerequisite for generalization, it weighs a lot in conclusions by analogy.

A postulate is a statement, a preliminary assumption of some scientific theory, which is taken as a starting point and becomes the basis for large theoretical generalizations.

The subject of science is interconnected forms of matter development or the peculiarities of their reflection in human consciousness.

The subject of scientific research is a separate aspect of the existence of the object of scientific research: the causes of the process or phenomenon, the patterns of its development, various properties, qualities, etc.

Applied scientific research is a type of cognitive activity aimed at determining ways of using the laws of nature to create new and improve existing ways and means of human activity; establishing how scientific knowledge obtained as a result of fundamental research can be used in practical activities.

A principle is a primary basis, a leading idea, a central concept that constitutes a generalization and extension of a certain position to all phenomena of the field of knowledge in which this principle was derived.

Psychological inertia of thinking is a subconscious effort to act in accordance with previous experience and knowledge, the use of standard methods, the influence of authorities, associated with fear of failure, resistance to criticism, too high self-criticism and other internal barriers.

Counting is a cognitive technique - finding a number that determines the quantitative ratio of objects of the same type or their parameters that characterize certain properties.

Referencing is the process of analytical and synthetic processing of a document, which consists in a concise presentation of the content of the primary document or its part with the main factual data and conclusions. In the process of abstracting, it performs semantic compression (squeezing) of the text. The result of the process is an essay that contains the topic, subject, object, purpose, method of conducting work, obtained results, conclusions, scope of use.

Development is the process and result of the transformation of new scientific and scientific and technical information obtained as a result of fundamental and applied research into a form suitable for implementation in practical activities.

Synthesis is a method of cognition, in which a practical or conventional combination of individual parts, signs, properties of an object is carried out into a single whole for its study. This makes it possible to reveal the general structure of the object, highlighting its main features. Inextricably linked with analysis.

System analysis is a scientific method of studying the object of research as a set of elements forming a system; involves evaluating the behavior of the object as a system with all the factors that affect its functioning. There is no single procedure for conducting system analysis in scientific research, but the methods of system dynamics, game theory, heuristic programming, simulation modeling, program-target management, etc. are widely used.

Socio-economic effectiveness of scientific research - the possibility of achieving elimination of hard labor, improvement of sanitary and hygienic working

conditions due to the implementation of the results of scientific research works; environmental protection, etc.

Sociology of science is a branch of science that studies the influence of material and production activities, the socio-economic system, and ideology on the functions of science in society.

Observation is a purposeful and organized perception of the external world in the absence of significant influence of the subject on the object. It is possible to use devices and tools that compensate for the natural limitations of human perception.

A standard is a regulatory and technical document that establishes a set of norms, rules, and requirements for a standardization object and is approved by a competent authority. Contains technical requirements and conditions, parameters and dimensions, types, designs, brands, assortments, acceptance rules, control methods, operation and repair rules, typical technological processes, etc.

Creativity is thinking in its highest form, which goes beyond what is known, as well as an activity that creates something new and includes setting or choosing a task, searching for conditions or a way to solve it and, as a result, creating something new.

The topic of scientific research is a component of a scientific problem, the solution of which makes it possible to obtain answers to a certain number of scientific questions covering part of the problem. Summarizing the results of a complex of topics within the limits of a scientific problem can provide its solution as a whole.

Theory is a system of generalized reliable knowledge about one or another fragment of reality, which describes, explains and predicts the functioning of a certain set of objects that make up this fragment. Theory is a mental, spiritual reflection and reproduction of reality.

The theory of science is a branch of science that constitutes a system of generalized knowledge about science, the main directions of its development, concepts and methodology.

Generalization is a scientific method that is a logical process of transition from the individual to the general, selection of a concept that defines the general that characterizes the objects of a certain class. Obtaining generalized knowledge means a deeper reflection of reality, penetration into its essence.

Formalization is a scientific method, which consists in the representation of an object or phenomenon in the symbolic form of some artificial language (mathematics, chemistry, etc.), which makes it possible to study real objects and their properties by means of a formal study of the corresponding signs.

Fundamental scientific research is a type of cognitive activity aimed at discovering and studying new phenomena and laws of nature, creating new principles of research, expanding scientific knowledge of society, establishing what can be used in practical human activity.

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