The National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute"

Ecology and technology of plant polymers

Research methodology

Work program of the discipline (Syllabus)

Details of the discipline	
Level of higher education	***Third (educational and scientific)***
Branch of knowledge	*natural Sciences*
Specialty	*101 Ecology*
Educational program	*Ecology*
Discipline status	*Normative*
Form of study	*full-time (day) / full-time (evening)*
Year of preparation, semester	*1 course, autumn semester*
The scope of discipline	*4 (120)*
Semester control / control measures	*Examination*
Lessons schedule	*2 hours per week (1 hour of lectures and 1 hour of practical classes)*
Language of instruction	*Ukrainian*
Information about the course leader / teachers	Lecturer: https://eco-paper.kpi.ua/pro-kafedru/vykladachi/vizytky/Ploskonos-Victor-Grigorovych.html Practical / Seminar: https://eco-paper.kpi.ua/pro-kafedru/vykladachi/vizytky/ Ploskonos-Victor-Grigorovych.html
Course placement	*https://do.ipo.kpi.ua/course/view.php?id=4395*

Curriculum

1. Description of the discipline, its purpose, subject of study and learning outcomes

The real form of development of science is scientific research.

This is the study of phenomena and processes, analysis of the influence of various factors on them, as well as the study of the interaction between phenomena using scientific methods in order to obtain proven and useful for science and practice solutions with maximum effect.

Scientific research is purposeful cognition, the result of which is a system of concepts, laws and theories.

The purpose of scientific research - the definition of a particular object and a comprehensive, reliable study of its structure, characteristics, relationships based on scientific principles and methods of cognition, the introduction into production of useful results.

There are two forms of research: basic and applied.

Fundamental research - scientific theoretical and (or) experimental activities aimed at gaining new knowledge about the patterns of development and relationship of nature, society, man.

Applied research is research carried out in sectoral research (design) institutions and aimed at obtaining and using knowledge for practical purposes.

Scientific result- new knowledge obtained in the process of basic or applied scientific research and recorded on the media of scientific information.

Every scientific study has an object and a subject.

If the object of scientific knowledge is the material world and forms of its reflection in the minds of people, the object of scientific research is a certain part of reality - a very specific subject or phenomenon, which is aimed at scientific activities of the researcher to know its essence, patterns and possibilities use in practice.

The process of choosing the object of study is complex because it significantly affects the focus and effectiveness of research in general.

***The subject of the discipline "Research Methodology »**-physical quantities and their measurements, the normal law of distribution of random variables, calculation of errors during indirect measurements of physical quantities, confidence interval of errors, development of plans of experimental researches and mathematical models with use of criteria of the maximum informativeness. Life experience shows that no measurement, no matter how carefully it is carried out, can be completely free from inaccuracies (errors).*

Since measurements are the basis of any scientific discipline, as well as the application of scientific research results, it is extremely important to be able to calculate these errors and minimize them.

To a large extent, the solution of the set tasks will be determined by the level of training of specialists working in the field of environmental protection, including institutions of environmental safety management of the state, scientific institutions and organizations, enterprises.

To successfully solve problems, specialists must be fluent in information, be able to solve complex problems of modeling situations at the highest scientific level.

The purpose of the discipline "Research methodology»

The purpose of studying this discipline is to form in graduate students a set of knowledge in the field of experimental planning and statistical processing of the results of experimental research and measurements during the study of a complex object in the subject area. In accordance with the purpose of training doctors of philosophy in this specialty requires the formation of graduate students with the following competencies:

- the ability to perform original research, to achieve scientific results that create new knowledge in the field of ecology and related interdisciplinary areas, to assess and ensure the quality of research;

- ability to use modern tools, electronic information resources, specialized software in scientific and educational activities, in particular for modeling processes and making optimal decisions in the field of ecology, nature protection and environmental management;

- ability to critically analyze, evaluate and synthesize new and complex ideas.

1.2. According to the requirements of the program of the discipline "Research Methodology ", students after its mastering must demonstrate the following program learning outcomes:

- plan and perform experimental and / or theoretical research on ecology, environmental protection and optimization of nature using modern tools, critically analyze the results of their own research and the results of other researchers in the context of the whole set of modern knowledge on the research problem;

- to develop and teach special disciplines related to the subject area of ecology in higher education institutions;

- apply modern tools and technologies to search for processing and analysis of information on environmental issues and related issues, in particular, statistical methods of data analysis of large volumes and / or complex structures, specialized databases and information systems;

- have modern conceptual knowledge and a high methodological level in the field of ecology and on the border of subject areas, as well as research skills sufficient for conducting scientific and applied research at the level of the latest world achievements.

2. Prerequisites and postrequisites of the discipline (place in the structural and logical scheme of education according to the relevant educational program)

*Study of the discipline«**Research methodology**»Is based on the principles of integration of various knowledge acquired by graduate students during the bachelor's and master's degree during the study of engineering disciplines. Discipline «**Research methodology**»Is the basis that should providesolving technical problems in the studied areas and aims to deeply rethink existing and create new holistic knowledge and professional practice.*

3. The content of the discipline

Section 1. Physical quantities and errors during their measurement

Topic 1 Physical quantities. Principles and methods of measuring physical quantities

Measured physical quantities. Principles and methods of measuring physical quantities. Basic concepts of probability theory and statistics.

Topic 2 Preliminary acquaintance with the theory of errors

Mistakes are like mistakes. Inevitability of errors. How important it is to know the mistakes. Estimation of an error at counting from a scale. Estimation of errors in the case of multiple direct measurements.

Topic 3 The main provisions of the theory of errors

Best estimate ± error. Significant figures in determining errors. The difference between the measurement results. Comparison of two values: measured and theoretically known. Comparison of two measured values. Relative errors. Significant figures in relative errors. Multiplication of two measured values.

Topic 4 Errors in indirect measurements

Errors of the sum and difference of measured values. Errors in multiplication and division of measured values. Errors when multiplying the measured value by the exact number. Errors when raising the measured value to the degree. Independent errors in calculating the sum of measured values. Generalizing formulas for calculating the sum, difference, product and fraction of measured values for independent errors. Errors when using a satisfactory function of one variable. Step-by-step error calculation method. General formula for calculating errors in indirect measurements.

Section 2 Methods of statistical analysis of random errors

Topic 1 Statistical analysis of multiple measurements with random errors

Random and systematic errors. Mean value and standard deviation. Standard deviation - as a unit measurement error. Standard deviation of the mean. Systematic errors for experimental research in educational laboratories.

Section 3. Substantiation of the law of distribution of random variables

Topic 1 Normal distribution of statistical value

Histograms and distribution of random variables. Marginal distribution of random variables. Normal distribution of a random variable.

Topic 2 The problem of screening and combining measurement results

Data screening problem. Chauvin's criterion. The problem of combining the results of different measurements.

Section 4. Informativeness of the experiment and mathematical methods of planning experimental research

Topic 1 Informativeness of experimental research

The concept of informativeness of the studied object. The classic approach to the study of an unknown object. Planning of experimental researches with use of criteria of informativeness.

Topic 2 Modeling of complex technological systems

The concept of modeling of complex technological systems in engineering and scientific activity.

Topic 3 Principles of mathematical self-organization of complex technological systems

Principles of mathematical self-organization of complex technological systems. Method of group consideration of arguments (MSUA). Methods of processing the results of experimental research.

4. Training materials and resources

Basic literature

1. *Korbutyak VI Methodology of systems approach and research: Textbook. manual / VI Корбутяк. - Rivne: NUVGP, 2010. - 176p.*
2. *Krushelnytska OV Methodology and organization of scientific research: textbook. manual. K .: Condor, 2006. 206 s.*
3. *Klimenyuk OV Methodology and methods of scientific research: Textbook. K .: Millennium, 2005. 186 p.*
4. *Sheiko V., Kushnarenko N. Organization and methods of research: Textbook. –K .: Knowledge –Press, 2003. –295 p.*
5. *Konversky AE Fundamentals of methodology and organization of scientific research, K .:, Center for Education. letters., 2010, 352 p.*
6. *Ivakhnenko AG Long-term forecasting and management of complex systems. –Kiev: Tehnika, 2005. - 312 p.*
7. *Taylor J. Introduction to error theory. Per. with English - M .: Mup, 1995. - 272 c.*

Additional literature

8. *Vasilkov Yu. V. Computer technologies of calculations in mathematical modeling: textbook. Manual / Yu. V. Vasilkov, NN Vasilkova. - M .: Finance and Statistics, 2002. - 256 p.*
9. *Buslenko NP Modeling of complex systems. - M .: Наука, 1998. - 356 c.*
10. *Ivakhnenko AG Inductive method of self-organization of models of complex systems. - Kiev: Scientific Opinion, 2001. - 296 p.*
11. *Golub VA Review of concepts of formation and use of library electronic resources // STI. –2001 –No 3. –C. 55 –58.*

Information resources on the Internet

8. *Ministry of Environmental Protection and Natural Resources of Ukraine - https://mepr.gov.ua/*
9. *Industrial ecology. Community of Environmentalists -http://www.eco.com.ua/*
10. *Professional Association of Ecologists of Ukraine(PAEU) -https://paeu.com.ua/*

Educational content

5. Methods of mastering the discipline (educational component)

Lectures

Lectures are aimed at:

- *providing modern, holistic, interdependent knowledge in the discipline "Research Methodology", the level of which is determined by the target setting for each topic;*
- *providing creative work of postgraduate students together with the teacher during the lecture;*
- *education of postgraduate students of professional and business qualities and development of their independent creative thinking;*
- *formation of postgraduate students' necessary interest and providing direction for independent work;*
- *definition at the current level of development of science in the field of research methodology;*
- *reflection of methodical processing of material (selection of the main provisions, conclusions, recommendations, clear and adequate to their formulations);*
- *use for demonstration of visual materials, combination, if possible, with demonstration of research results;*
- *teaching research materials in clear and high-quality language with observance of structural and logical connections, explanation of all newly introduced terms and concepts;*
- *accessibility for perception by this audience.*

№ s / n	***Title of the lecture topic and list of main questions (list of teaching aids, references to literature and tasks on VTS)***	***Hours***
1	***Physical quantities. Principles and methods of measuring physical quantities Preliminary acquaintance with the theory of errors*** *Lecture № 1. Measured physical quantities. Principles and methods of measuring physical quantities. Mistakes are like mistakes. Inevitability of errors. How important it is to know the mistakes. Estimation of an error at counting from a scale. Estimation of errors in the case of multiple direct measurements.* *Literature: [7] p12-21; [1] p.6-14; [5].* *Tasks on VTS. Systems of physical quantities and their units. Indicators of accuracy and forms of presentation of measurement results. General provisions and classification of errors.*	*1*
2	***Topic 3The main provisions of the theory of errors*** ***Topic 4Errors in indirect measurements*** *Lecture № 2. Best grade ± error. Significant figures in determining errors. The difference between the measurement results. Comparison of two values: measured and theoretically known. Comparison of two measured values. Relative errors. Significant figures in relative errors. Multiplication of two measured values* *Literature: [7] p. 49-64; [1] p.16-22.* *Tasks on VTS. Comparison of two measured values. Relative errors.*	*2*
3	***Section 2 Methods of statistical analysis of random errors*** ***Topic 1Statistical analysis of multiple measurements with random errors*** *Lecture № 3. Random and systematic errors. Mean value and standard deviation. Standard deviation - as a unit measurement error. Standard deviation of the mean. Systematic errors for experimental research in educational laboratories.* *References: [7] p.87-101, [1] c.34-63, [2] p. 49-64.* *Tasks on VTS. Systematic errors for experimental research in educational laboratories.*	*2*
4	***Section 3. Substantiation and verification of the law of distribution of random variables.*** ***Topic 1Normal distribution of statistical value*** *Lecture № 4. Histograms and distribution of random variables. Marginal distribution of random variables. Normal distribution of a random variable.* *References: [7] p.106-130, [3] p.54-72, [9] p. 88-101.*	***1***

	Tasks on VTS. Probability distribution law for multiple measurements. Random variables. Use of elements of probability theory to measurement results. Repetition of tests - binomial distribution.	
5	***Topic 2The problem of screening and combining measurement results*** *Lecture № 5. The problem of data screening. Chauvin's criterion. The problem of combining the results of different measurements.* *Literature: [7] p. 148-152; [5] c. 18-58.* *Tasks on VTS. The problem of data screening using the Chauvin criterion on examples. The problem of combining the results of different measurements on examples.*	***2***
6	***Section 4. Informativeness of the experiment and mathematical methods of planning experimental research*** ***Topic 1Informativeness of experimental researches*** *Lecture 6.The concept of informativeness of the studied object. The classic approach to the study of an unknown object. Planning of experimental research (classical). Planning of experimental researches with use of criteria of informativeness.* *Literature: [10] p. 13-36; [11] p. 33-47, [5] p.59-73.* *Tasks on VTS. Planning of experimental researches with use of criteria of informativeness.*	***1***
7	***Topic 2 Modeling of complex technological systems*** *Lecture 7.The concept of modeling of complex technological systems in engineering and scientific activity.* *Lecture 8.Preliminary research of the technological system. Classification of factors influencing the technological system. Properties of the studied factors. Methods for estimating the strength of the influence of factors on the initial parameter. Method of expert assessments (rank correlation).* *Literature: [9] p. 38-45; [10], [11] c. 49-66.* *Tasks on VTS. Systematic and random errors. Standard deviation. Determination of random errors. Experiment error. Checking for homogeneity of measurement results. Processing of research results on a PC. Databases. Trend lines.*	***2***
8	***Topic 3Principles of mathematical self-organization of complex technological systems*** *Lecture 9.Principles of mathematical self-organization of complex technological systems. Method of group consideration of arguments (MSUA). Criteria for maximum informativeness and noise resistance of the experiment. Methods of processing the results of experimental research.* *Literature: [11] p. 70-98; [16], [9] p. 51-73.* *Tasks on VTS. Method of self-organization of complex technological systems. Features of the algorithm of group accounting of arguments (MSUA). Advantages of the method of self-organization in comparison with the classical method of experiment planning.*	***2***
	Total	***13***

Practical training

In the system of professional training of graduate students in this discipline, practical classes occupy 50% of the classroom workload. As a supplement to the lecture course, they lay and form the basis of the qualification of the doctor of philosophy. The content of these classes and methods of conducting them should ensure the development of creative activity of the individual. They develop scientific thinking and the ability to use special terminology, allow you to test knowledge, so this type of work is an important means of operational feedback. Practical classes should perform not only cognitive and educational functions, but also contribute to the growth of graduate students as creative workers.

The main tasks of the cycle of practical classes:

- *to help graduate students to systematize, consolidate and deepen the knowledge of a theoretical nature in the field of modern methods of error theory and modeling of complex systems;*
- *to teachgraduate students techniques for solving practical problems, to promote the acquisition of skills and abilities to perform calculations, graphics and other tasks;*
- *to teachwork with scientific and reference literature;*
- *to form skillslearn independently, ie master the methods, techniques and techniques of self-learning, self-development and self-control.*

№ s / n	The name of the topic of the practical lesson and a list of basic questions (list of didactic support, references to literature and tasks on VTS)	Hours
1	**Practical lesson 1.** General concepts of physical quantities. Systems of physical quantities. Finding out the causes of errors. The main provisions of the theory of errors. Solving problems for the purpose of the general estimation of errors in case of repeated measurements. Relative errors and significant figures. Literature: [7] p12-21; [1] p.6-14; [5] p. 16-23. Tasks on VTS. Solving problems for the purpose of general estimation of errors in case of repeated measurements in laboratory conditions.	1
2	**Practical lesson 2.** Errors in indirect measurements. Determination of errors when using measurement results in the operations of sum, difference, multiplication and divisionLiterature: [7] p. 49-64; [1] p.16-22. Tasks on VTS. Errors in indirect measurements in the laboratory.	1
3	**Practical lesson 3.** Statistical analysis of random errors. Calculation of mean and standard deviation. References: [7] p.87-91, [1] c.34-43, [2] p. 49-54. Tasks on VTS. Calculation of mean and standard deviation in the laboratory.	2
4	**Practical lesson 4.** Statistical analysis of random errors. Calculation of the standard deviation of the mean. Systematic errors. References: [7] p.92-101, [1] c.44-63, [2] p. 55-64. Tasks on VTS. Calculation of standard deviation of the mean in the laboratory.	2
5	**Practical lesson 5.** Solving problems on screening and combining measurement results. Literature: [7] p. 148-152; [5] c. 18-58. Tasks on VTS. Elimination and integration of measurement results in the laboratory in the laboratory.	2
6	**Practical lesson 6.** Analysis of a complex technological system. Choice of factors. Determination of levels of variation for the formation of a matrix of experimental studies. Literature: [9] p. 38-45; [10], [11] c. 49-66. Tasks on VTS. Determination of levels of variation in the laboratory.	2
7	**Practical lesson 7.** Formation of a matrix using informative criteria. Literature: [11] p. 70-78; [16], [9] p. 51-63. Tasks on VTS. Matrix formation in laboratory conditions.	1
8	**Practical lesson 8.** Development of models by the method of self-organization of complex technological systems. Literature: [11] p. 79-98; [16], [9] p. 63-73. Tasks on VTS. Development of models based on laboratory results.	2
	Total	**13**

6. Independent work of a student / graduate student

Independent work takes 70% of the time to study the credit module, including preparation for the exam. The main task of independent work of graduate students is to master scientific knowledge in areas

that are not included in the list of lecture questions through personal search for information, the formation of an active interest in the creative approach in educational work. In the process of independent work within the educational component, the graduate student must learn to analyze modern methods of assessing the accuracy of the results and develop mathematical models.

№ s / n	*The name of the topic that is submitted for independent study*	*Number of hours of VTS*
	Section 1. Physical quantities and errors during their measurement	
1	***Topic 1Physical quantities. Principles and methods of measuring physical quantities.****Systems of physical quantities and their units. Indicators of accuracy and forms of presentation of measurement results.* *Literature: [1] p. 50-54; [2] c. 14-35.* ***Topic 2Preliminary acquaintance with the theory of errors.****General provisions and classification of errors. Point characteristics of errors. Interval characteristics of errors. .* *Literature: [2] p. 69-82.* ***Topic 3The main provisions of the theory of errors.****Classification of measurement errors. Influence of systematic errors on measurement results. Proportionality check using a graph.* *References: [1] p.34-38; [4] c. 17-24, [5] p. 34-48 ,.* ***Topic 4Errors in indirect measurements.****General information about errors in indirect measurements. Understanding errors in indirect measurements by examples. The principle of the arithmetic mean.* *Literature: [2] p. 51-70; [3] p.49-78, [9] c. 50-54.*	*18*
	Section 2 Methods of statistical analysis of random errors	
2	***Topic 1Statistical analysis of multiple measurements with random errors****. Determination of the warranty interval of measurement results. Summation of measurement errors. Errors of direct equilateral measurements. Processing and evaluation of accuracy of equilibrium measurements. Standard deviation of the average of the examples.* *Literature: [2] p. 73-118; [3] c.98-101, [5] c.93-106.*	*18*
	Section 3. Substantiation and verification of the law of distribution of random variables	
3	***Topic 1Normal distribution of statistical value.****Probability distribution law for multiple measurements. Random variables. Use of elements of probability theory to measurement results. Repetition of tests - binomial distribution.* *References: [7] p.106-130, [3] p.54-72, [9] p. 88-101.* ***Topic 2 The problem of screening and combining measurement results.****The problem of data screening using the Chauvin criterion on examples. The problem of combining the results of different measurements on examples.* *Literature: [7] p. 148-152; [5] c. 18-58.*	*14*

Section 4. Informativeness of the experiment and mathematical methods of planning experimental research		
4	***Topic 1Informativeness of experimental researches.****Planning of experimental researches with use of criteria of informativeness.* *References: [11] p.46-60.* ***Topic 2Modeling of complex technological systems.****Systematic and random errors. Standard deviation. Determination of random errors. Experiment error. Checking for homogeneity of measurement results. Processing of research results on a PC. Databases. Trend lines.* *Literature: [5] p. 38-121, [10] p.78-91.* ***Topic 3 Principles of mathematical self-organization of complex technological systems.****Method of self-organization of complex technological systems. Features of the algorithm of group accounting of arguments (MSUA). Advantages of the method of self-organization in comparison with the classical method of experiment planning.* *Literature: [10] p. 134-160; [5] p.77-90, [11] p. 94-119, [12] p.57-74.*	*14*
5	*Exam preparation*	*30*
	Hours in general	*94*

Policy and control

7. Course policy (educational component)

Rules for attending classes and behavior in class

Postgraduate students are obliged to take an active part in the educational process, not to be late for classes and not to miss them without good reason, not to interfere with the teacher to conduct classes, not to be distracted by actions that are not related to the educational process.

Rules for assigning incentive and penalty points

- *Incentive points can be accrued by the teacher only for the performance of creative work in the discipline or additional passing of online profile courses with the receipt of the relevant certificate:*
- *https://www.coursera.org/learn/research-methods;*
- *https://ru.coursera.org/learn/metodologiya-nauchnyh-issledovanij-kotiki.*

But their amount cannot exceed 25% of the rating scale.

- *penalty points within the academic discipline are not provided.*

Policy of deadlines and rearrangements

In the event of arrears of the discipline or any force majeure, graduate students should contact the teacher through available (provided by the teacher) communication channels to resolve problems and agree on an algorithm for practice.

The policy of academic integrity

Plagiarism and other forms of dishonesty are not allowed. Plagiarism includes the lack of links for the use of printed and electronic materials, citations, opinions of other authors. Inadmissible hints and write-offs when writing tests, conducting classes; passing the exam for another graduate student; copying of materials protected by the copyright system without the permission of the author of the work.

The policy and principles of academic integrity are defined in Section 3 of the Code of Honor of the National Technical University of Ukraine "Kyiv Polytechnic Institute named after Igor Sikorsky". Read more:https://kpi.ua/code

Policy of academic behavior and ethics

Postgraduate students must be tolerant, respect the opinion of others, formulate objections in the correct form, constructively maintain feedback in the classroom.

Norms of ethical behavior of students and employees are defined in Section 2 of the Code of Honor of the National Technical University of Ukraine "Kyiv Polytechnic Institute named after Igor Sikorsky". Read more:https://kpi.ua/code

8. Types of control and rating system for evaluation of learning outcomes (RSO)

Distribution of study time by types of classes and tasks in the discipline according to the working curriculum:

Semester	Training time		Distribution of teaching hours				Control measures		
	Loans	acad. year	Lectures	Practical	Lab. slave.	CPC	MCR	RR	Semester control
1	4	120	13	13	-	94	-	-	Exam

The student's rating in the discipline consists of points that he receives for:

The graduate student's rating from the credit module consists of the points he receives for his work in practical classes.

Semester control is an exam.

System of rating (weight) points and evaluation criteria

Rating points system and evaluation criteria:

Performing tasks in practical classes.

The weight score on the 1st and 2nd practical classes is 4 points each; in practical classes 3-7 - 6 points, in practical classes -8 - 7 points.

The maximum number of points in all practical classes = (2x4) + (5x6) + 7 = 45 points.

Provided good preparation and active work in a practical lesson - 1 point. One or two best students in each practical session can be given 1 point as an incentive.

The maximum sum of points of the starting component is 45.

A prerequisite for admission to the exam is a starting rating of at least 23 points.

According to the results of educational work for the first 7 weeks, the "ideal student" must score 16 points. At the first attestation (8th week) the student receives "credited" if his current rating is not less than 0.5x 16 = 8 points.

According to the results of 13 weeks, the "ideal student" must score 32 points. At the second attestation (14th week) the student receives "credited" if his current rating is not less than 0.5x32 = 16 points.

The size of the examination scale is RE = 55 points (55% of R)

Conditions for admission to the exam:*starting rating not less than 23 points (rc ≥ 23 points, not less than 50% of RS).*

Examination evaluation criteria

The examination ticket contains one theoretical question, which has a weight score of 30, and one practical task, which has a weight score of 25. The maximum number of points is 30 + 25 = 55 points.

Theoretical evaluation system:

– *"Excellent", complete answer (not less than 90% of the required information) - 30-28 points;*

– *"Good", a fairly complete answer (at least 75% of the required information, or minor inaccuracies) - 23-22 points;*

– *"Satisfactory", incomplete answer (not less than 60% of the required information and some errors) - 18-16 points;*

– *"Unsatisfactory", unsatisfactory answer - 0 points.*

***Evaluation system of practical issues**:*

– *"Excellent", complete answer (not less than 90% of the required information) - 23-22 points;*

– *"Good", a fairly complete answer (at least 75% of the required information, or minor inaccuracies) - 19-17 points;*

– *"Satisfactory", incomplete answer (not less than 60% of the required information and some errors) - 15-13 points;*

– *"Unsatisfactory", unsatisfactory answer - 0 points.*

The sum of starting points and points for answering the questions of the exam ticket is transferred to the exam score according to the table:

Scores	***Rating***
95 ... 100	*perfectly*
85 ... 94	*very good*
75 ... 84	*fine*
65 ... 74	*satisfactorily*
60 ... 64	*enough*
RD<60	*unsatisfactorily*
Admission conditions are not met	*not allowed*

9. **Additional information on the discipline (educational component)**

An approximate list of questions that are submitted for semester control

theoretical part

1. *Justify the concept and provide a formula for calculating the relative error.*
2. *Justify the concept of measurement accuracy due to relative error.*
3. *Justifyuse of the concept of relative error in the formula for calculating the error of obtaining measurement results.*
4. *Analyze and provide a rule for calculating the error of the sum and difference of two independent measured values.*
5. *Analyze the rules for calculating the error used when measuring independent measured values.*
6. *Analyze and providethe rule for calculating the error of the sum and difference of quantities, the rule for the error of the product and the division of measurement results, as well as the rule for the product of the measurement result by the exact number.*
7. *Justifyuse of the rule of calculation of an error at raising of the measured size to degree.*

8. *Analyze and provide a formulaestimating the error using a satisfactory function of one variable in the case of indirect measurements.*
9. *Justify the use ofgeneral formula for calculating errors in indirect measurements and the method "step by step".*
10. *To substantiate the essence of the problem of combining the results of the experiment and to determine the formulas for calculating the weighted average.*
11. *Define the difference between the measurement results, assess the significance (insignificance) of the difference, based on the concept of best estimate and error.*
12. *Analyze and provide a formula for calculating the standard deviation of the mean.*
13. *Analyze and provide ncalculated the error of the difference between the measurement results.*
14. *Analyze and provideformulas for calculating the value of the criterion χ2.*
15. *To substantiate the essence of the problem of combining the results of the experiment and to determine the formulas for calculating the weighted average.*
16. *Analyze and provide a sequence of formulas for calculating the confidence interval.*
17. *Justify the scheme of using the Chauvin criterion.*
18. *To substantiate the essence of the problem of combining the results of the experiment and to determine the formulas for calculating the weighted average.*
19. *Analyze and provide formulas for statistical processing of measurement results, namely: calculation of the mean value and standard deviation of the mean.*

20. Analyze the formulaestimating the error using a satisfactory function of one variable in the case of indirect measurements.

21. Justify the scheme of using the Chauvin criterion.

22. Analyze and provideformulas and determine the sequence (algorithm) of using formulas to prove whether a normal sample of observations corresponds to the normal Gaussian distribution.

23. Analyze and provideformulas for calculating the value of the criterion χ2.

24. Analyze and provide formulas for statistical processing of measurement results, namely: calculation of the mean value and standard deviation of the mean.

Tasks

1. Apply the formula for calculating the relative error (as a percentage) for five measurements:
- measured height = 5.03 ± 0.04 m;
- measured time = 19.5 ± 1 s;
*- measured charge = (-3.2 ± 0.3) * 10-19 Cl);*
*- measured wavelength = (0.56 ± 0.07) * 10-6 m);*
*- measured pulse = (3.27 ± 0.04) * 103 g * cm / s).*

2. Use the concept of measurement accuracy due to the relative error for the case, namely: assume that you want to measure a length of 2 cm with an accuracy of 1%. With the help of a wooden ruler you can count with an accuracy of 1 mm, and with a microscope - up to 0.1 mm.
Is it possible to do this with a wooden ruler? Using a microscope?

3. Use the formula for calculating the error of the measurement results in the case when two values of a and b are measured (length and width of a paper strip for strength testing). We obtain: a = 11.5 ± 0.2 cm and b = 25.4 ± 0.2 cm

*It is necessary to calculate the value of the area of the strip S = a * b, the absolute and relative value of the error in S, as well as the relative value of the errors of the measured values?*

4. Use the rule of calculating the error of the sum and difference of two independent measured values in the case of:

The laboratory assistant mixes solutions of chemical reagents from two bottles, having previously measured separately weights of these filled and then empty bottles and having received as a result:

M1 is the mass of the first bottle and its contents = 540 ±10 years;

m1 = mass of the first empty bottle = 72 ±1 year;

M2 = mass of the second bottle and its contents = 940 ±20 years;

m2 = mass of another empty bottle = 97 ±1 year.

It is necessary to determine the total mass of chemical reagents, calculate the error of the total mass and record the final result.

5. Use the error calculation rules used when measuring independent measured values in the case of: The specialist received the following measurement results:

a = 5 ± 1 cm; b = 18 ± 2 cm; c = 12 ± 1 cm; t = 3.0 ± 0.5 s; m = 18 ± 1 g

Using the rules of error of the sum (difference) of measurement results and the product and division of measurement results, calculate the errors and relative errors (in%):

*a) a + b + c; b) a + c-c; c) c * t; d) 4a; e) b / 2 (where the numbers 4 and 2 have no error), e) m * b / t.*

6. Use the rules of calculation: errors of sum and difference of values, errors of product and division of measurement results, product of measurement result by exact number when calculating the following expressions:

*a) (5 ± 1) + (8 ± 2) - (10 ± 4); b) (5 ± 1) * (8 ± 2);*

*c) (10 ± 1) / (20 ± 2); d) 2π * (10 ± 1) (digits π and 2 have no error).*

7. Use the rule of calculating the error when raising the measured value to the degree in the case when the experimenter determines the acceleration of free fall g, measuring the time t of falling stone from a height h (h is determined by the known formula h = $(\frac{1}{2})g * t^2$ *).*

After several measurements of time, he finds:

t = 1.6 ± 0.1 s and measures the height h as h = 14.1 ±0.1 m.

8. Use the formula for estimating the error using a satisfactory function of one variable in the case: the angle ϑ was measured as 125 ± 2 deg. This value is then used to calculate Sin ((.

It is necessary to calculate Sin (ϑ) and error.

*9 Use the general formula for the calculation of errors in indirect measurements and the method "step by step" on the example of calculating a certain value of c = a * in:*

a = 10.0 ± 0.5H; in = 15 ± 1 cm.

10. The experimenter measures the density of the liquid five times and gets the results (in g / cm3): 1.8; 2.0; 2.0; 1.9; 1.8.

What about the best estimate and error based on its measurements?

*11. It is necessary to accurately measure the area (S) of a rectangular sample of paper intended for testing with a size of 2.5 cm * 5.0 cm.*

In the table. the results of 10 measurements of width (l) and length (c) of the sample are given.

Measurement value	*Measured values*
L	*24.25; 24.26; 24.22; 24.28; 24.24;*
	24.25; 24.22; 24.26; 24.23; 24.24.
B	*50.36; 50.35; 50.41; 50.37; 50.36;*
	50.32; 50.39; 50.38; 50.36; 50.38.

In order to measure the area (S) of a rectangular paper sample, it is necessary, respectively, to calculate the average value of both values, the standard deviation σ_x and the standard deviation of the mean $\sigma_{\bar{x}}$ using appropriate formulas.

12. Calculate the errors of the difference of measurement results in order to compare the two measured values and use it for the case:

In the experiment to verify the law of conservation of momentum, the student obtained for the initial and final moments (L and L ') the values given in the table.

Do I need to add additional columns to the table for the difference (L - L ') and error and check whether the student's results are consistent with the law of conservation of momentum?

Initial (L)	The final L '
3.0 ± 0.3	2.7 ± 0.6
7.4 ± 0.5	8.0 ± 1.0
14.3 ± 1.0	16.5 ± 1.0
25 ± 2	24 ± 2
32 ± 2	31 ± 2
37 ± 2	41 ± 2

13. Determine (with the filling of free graphs in the table) whether the normal Gaussian distribution corresponds to a sample of observations of the growth of 200 aborigines on an island, which are shown in the table:

Bean number	Growth in the bean	The number of observations Ok in the bean	The expected number Ek	Pk,%
1	less than X-1.5σ	14		
2	between X-1.5σ and X-σ	29		
3	between X-σ and X-0.5σ	30		
4	between X-0.5σ and X	27		
5	between X and X + 0.5σ	28		
6	between X + 0.5σ and X +σ	31		
7	between X +σ and X + 1.5σ	28		
8	more than X + 1.5σ	thirteen		

14. Calculate the confidence interval in the case where the experimenter repeatedly measures the value of g, the acceleration of free fall, and gets a result of 9.5 m / s2 and a standard deviation of 0.1.

If we assume that the results of its measurements are normally distributed with a center equal to the accepted value of 9.8 m / s2 and a width of 0.1, then what is the probability of obtaining a result that differs from 9.8 m / s2 as (or more) as the result of the experimenter ?

Assuming that the experimenter did not actually make mistakes, can it be said that his experiment was probably influenced by some undetected systematic errors?

15. Two measurements of the destructive force P give the results: 334 ± 1 and 336 ± 2.

Can these two results be considered consistent?

If so, you need to calculate the best estimate of P and its error.

16. Determine whether to discard a questionable measurement result in the case of:

The specialist measures the thickness of the cardboard H ten times and gets the results (in mm): 0.86; 0.83; 0.87; 0.84; 0.82; 0.95; 0.83; 0.85; 0.89; 0.88.

a) You need to calculate the average value $\overline{H}$ and standard deviation σ_H these results.

b) If a specialist decides to use the Chauvin criterion, should he reject the result of 0.95 mm? It is necessary to justify the concession.

17. Use the formulas for calculating the mean and standard deviation of the mean for the case: The specialist measures the value of x five times and gets the results: 5, 7, 9, 7, 8.

It is necessary to calculate $\bar{x}$ *and standard deviation* σ_x*. Compare the two options (with N and N-1) during the calculation* σ_x*.*

18. Use the formula for estimating the error using a satisfactory function of one variable in the case of indirect measurements: the angle ϑ was measured as θ *= 20 ± 3 deg. This value is then used to calculate Cos* θ*.*

It is necessary to calculate Cos θ *and error.*

19. Determine whether to discard a questionable measurement result in the case of:

The specialist performs 14 measurements of the oscillation period of the generator and gets the results (in fractions of a second): 7, 3, 9, 3, 6, 9, 8, 7, 8, 12, 5, 9, 9, 3

Feeling that the result (12) is too large, the specialist decides to use the Chauvin criterion. Will he reject this result? How many results, as different from the average as 12, should he expect?

20. Use the formula for estimating the error using a satisfactory function of one variable in the case of indirect measurements: the angle ϑ was measured as θ *= 20 ± 3 deg. This value is then used to calculate Cos* θ*.*

It is necessary to calculate Cos θ *and error.*

21. Determine the value of the criterion χ2 for a sample of 40 measurements x1, x2,… x40 the length of the trajectory x of a bullet flying out of a gun (the results are shown in the table).

731	772	771	681	722	688	653	757	733	742
739	780	709	679	760	748	672	687	766	645
678	748	689	810	805	778	764	753	709	675
698	770	754	830	725	710	738	638	787	712

22. Calculate the mean and standard deviation of the results of ten measurements of one of the indicators that characterize the quality of the paper (for example, the smoothness of the paper): 86, 85, 84, 89, 86, 88, 88, 85, 83, 85.

23. Calculate the confidence interval in the case where the experimenter wants to check the law of conservation of energy for a particular nuclear reaction. To this end, he conducts an experiment and obtains the results of the initial and final energy, respectively, Ep = 75 $\pm$ *3 MeV and Eq = 60* $\pm$ *9 MeV, where the standard deviations of the results are given as errors.*

Is this difference significant (at 5% level)? It is necessary to give a reasoned answer to the question.

Work program of the discipline (syllabus):

Folded*Associate Professor, Ph.D., Ploskonos VG*

Approved*department ___ E and TRP ___ (protocol № 14 from 08 .06.2022)*

Agreed*Methodical commission of the faculty (protocol №10 from 24.06.2022)*