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

Ecology and technology of plant polymers

Basics of metrology and theory of errors

Working program of the academic discipline (Syllabus)

Details of the academic discipline	
Level of higher education	***Second (master's)***
Branch of knowledge	*10 Natural sciences*
Specialty	***101 Ecology***
Educational program	***Ecological safety***
Discipline status	*Selective*
Form of education	*full-time (day)//distance/mixed*
Year of training, semester	*1st year, spring semester*
Scope of the discipline	*4.0 credits (120 hours)*
Semester control/ control measures	*Assessment/Modular test papers*
Lessons schedule	*2 hours per week (1 hour of lectures + 1 hour of practical classes)*
Language of teaching	*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
Placement of the course	https://do.ipo.kpi.ua

Program of educational discipline

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

The knowledge acquired in the process of studying the educational discipline provides an opportunity to acquire the skills of the basics of metrology and support in the appropriate state of measuring equipment (MT) for the proper metrological support of the technological processes of processing plant raw materials and protecting the environment from negative anthropogenic influence. The ability to process and analyze and apply the basics of measurement accuracy during experimental research is formed; statistical analysis of repeated measurements performed in industrial and laboratory conditions.

Subject of the educational discipline "Fundamentals of Metrology and Theory of Errors"*- this is mastering the basics of metrological support and using the acquired knowledge in the process of performing experimental research. Life experience shows that no research, no matter how carefully it is carried out, cannot be performed without knowledge of the basics of metrology, as well as mathematical processing of the experiment and the accuracy of measurement and evaluation of results.*

To a large extent, the solution of the set tasks will be determined by the level of training of specialists who solve the issue of resource conservation, including scientific institutions and organizations, enterprises.

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

The purpose of the educational discipline "Fundamentals of metrology and theory of errors"

The goal of the educational discipline is the formation of students' competencies:

- ability to generate new ideas (creativity);

- the ability to search, process and analyze information from various sources;

- awareness at the level of the latest achievements, necessary for research and/or innovative activities in the field of ecology, environmental protection and balanced nature management;

- the ability to coordinate trends in the use of resources with the use of computer information technologies.

1.2. According to the requirements of the program of the educational discipline "Fundamentals of Metrology and Theory of Errors", after mastering it, students must demonstrate the following learning outcomes:

- to be able to use conceptual ecological regularities in professional activity;

- critically analyze theories, principles, methods and concepts from various subject areas to solve practical problems and problems of ecology;

- to know modern approaches to the organization of ecologically clean productions, reorganization and reconstruction of existing productions from the standpoint of resource conservation, taking into account the life cycle of the product.

2. Pre-requisites and post-requisites of the discipline (place in the structural and logical scheme of training according to the relevant educational program)

Studying the discipline"Fundamentals of Metrology and Theory of Errors" is based on the principles of integration of various knowledge acquired by students during the bachelor's and the 1st semester of master's studies during the study of engineering disciplines. The discipline "Fundamentals of Metrology and Theory of Errors" is the foundation that should providesolution of technical problems and aimed at deep rethinking of existing and creation of new holistic knowledge and professional practice.

3. Content of the academic discipline

CHAPTER 1 METROLOGY AND FUNDAMENTALS OF ERROR THEORY

Topic 1 The essence of metrology and the basics of error theory. Tasks and functions of metrology

Measured physical quantities. Systems of physical quantities and their units. Principles and methods of measuring physical quantities. The accuracy of measurement of physical quantities.

Topic 2 Measuring equipment

Means of measuring equipment, classification of measuring equipment and their purpose. Structure and parameters of measuring equipment. Accuracy indicators and forms of presentation of measurement results.

Topic 3 State metrological service of Ukraine

Structure and functions of metrological service of Ukraine. Law on metrology: basic concepts and definitions.

Topic 4 Metrological assurance of unity and accuracy of measurements

Metrological assurance of unity and accuracy of measurements. State metrological control and supervision. State metrological service of the enterprise. Metrology as a scientific basis of unity and accuracy of measurements. State metrological control and supervision.

Topic 5 Metrological certification, verification and calibration of measuring equipment to ensure their accuracy

Metrological attestation, verification and calibration of measuring equipment. Methods of verification of FTAs. Metrological certification of measuring equipment. Verification methods (calibration). Verification schemes. Metrological verification of measuring equipment. Types of metrological checks. Organization and procedure of metrological verification.

Topic 6 International and regional metrology organizations

International metrology organizations. International Organization of Weights and Measures. International Organization of Legislative Metrology. Regional metrology organizations. Metrology in the countries of Western Europe. Metrology in the USA. Metrology in some countries of Eastern and Central Europe.

Metrological examination of technical documentation. General provisions and tasks of metrological examination. Organization and procedure of metrological examination. Metrological examination of design documentation. Metrological examination of technological documentation.

Topic 7 Basic principles of measurement accuracy according to the theory of errors

Best estimate ± deviation. Significant numbers with defined deviations. The difference between the measurement results. Comparison of two values: measured and theoretically known. Comparison of two measured values. Multiplication of two measured values.

4. Educational materials and resources

Basic literature

1. Nesterchuk D.M., Kvitka S.O., Halko S.V.. Basics of metrology and measuring tools: a study guide / – Melitopol: Publishing and printing center "Lux", 2017. - 256 p.

2. Bozhenko L.I. Metrology, standardization, certification and accreditation. – Lviv: Afisha, 2006. - 324 p.

3. Vasilevskyi O.M., Kucheruk V.Yu., Volodarskyi E.T. Basics of the theory of measurement uncertainty: Textbook / – Vinnytsia: VNTU, 2015. – 230 p.

Additional literature

4. Law of Ukraine on metrology and metrological activity, No. 1765, Kyiv, June 15, 2004.

5. Volodarskyi Y.T., Kuharchuk V.V., Podzharenko V.O., Serdyuk G.B. Metrological support of measurements and control. Study guide for technical students. university - Vinnytsia: Published. State, Technical University, 2001.-220 p.

6. DSTU 3651.2-97 Metrology. Units of physical quantities. Basic units of physical quantities. International systems of values. Basic provisions, names and designations.

10. Primakov SP., Barbash V.A. Technology of paper and cardboard. K.: ECMO, 2002.-396 p.

11. DSTU 2926-94 Quality systems. Complexes of quality management are system and technological. Substantive provisions.

Information resources on the Internet

1.Ministry of Environmental Protection and Natural Resources of Ukraine -https://mepr.gov.ua/

2.Industrial ecology. Community of environmental specialists -http://www.eco.com.ua/

*3.**Professional Association of Environmentalists of Ukraine**(PAEU) –https://paeu.com.ua/*

4.Library named after V.I. Vernadsky -www.nbuv.gov.ua

5.Ecological portal of Ukraine -www.ecologya.com.ua

Educational content

5. Methods of mastering an educational discipline (educational component)

Lecture classes

Lectures are aimed at:

- provision of modern, integral, interdependent knowledge in the discipline "Fundamentals of Metrology and Theory of Errors", the level of which is determined by the target attitude to each specific topic;

- ensuring creative work of students together with the teacher during the lecture;

- education of students' professional and business qualities and development of their independent creative thinking;

- forming the necessary interest in students and providing direction for independent work;

- definition at the current level of scientific development in the field of standardization, metrology and accuracy of measurements;

- reflection of the methodical processing of the material (highlighting of the main provisions, conclusions, recommendations, their wording is clear and adequate);

- the use of visual materials for demonstration, combining them, if possible, with the demonstration of research results;

- teaching research materials in clear and high-quality language with observance of structural and logical connections, clarification of all newly introduced terms and concepts;

- accessibility for perception by this audience.

No. z/p	The name of the topic of the lecture and a list of the main questions (a list of didactic tools, references to the literature and tasks on the SRS)	Hour
1	**CHAPTER 1 METROLOGY AND THE BASICS OF ERROR THEORY** **Topic 1 The essence of metrology and the basics of error theory. Tasks and functions of metrology** *Lecture No. 1. Tasks and functions of metrology and the basics of error theory. Law on metrology: basic concepts and definitions.* *Literature: [1] p.10-23; [2] p.6-14, [3] p.7-19, [4] p.128-134.* *Tasks on SRS Principles and methods of measuring physical quantities.*	4
2	**Topic 2. Means of measuring technology (MET), classification of MT and their purpose** *Lecture No. 2. Measuring equipment, their classification and purpose. Structure and parameters of measuring equipment.Literature: [1] pp. 30-43; [2] pp. 16-34, [4] pp. 137-149, [14] pp. 28-44.* *Tasks on SRS Accuracy indicators and forms of presentation of measurement results.*	2
3	**Topic 3 State metrological service of Ukraine** *Lecture No. 3. Structure and functions of metrological service of Ukraine.* *Literature: [1] pp. 48-63; [2] pp. 36-44, [4] pp. 152-164, [14] pp. 48-64.* *Tasks on SRS Law on metrology: basic concepts and definitions.*	2
4	**Topic 4 Metrological assurance of unity and accuracy of measurements. State metrological control and supervision. Metrological service of the enterprise** *Lecture No. 4. Metrology as a scientific basis for the unity and accuracy of measurements. State metrological control and supervision.* *Literature: [2] p.48-66; [3] pp. 56-74, [4] pp. 166-184, [14] pp. 68-86.* *Tasks on SRS State metrological service of the enterprise (organization).*	**2**
5	**Topic 5 Metrological attestation, verification and calibration of measuring equipment. Methods of verification of FTAs** *Lecture No. 5. Metrological certification of measuring equipment. Verification*	**2**

	methods (calibration). Verification schemes. *Literature: [2] p.68-96; [3] pp. 76-94, [4] pp. 186-199, [14] pp. 88-106.* *Tasks on SRS Metrological verification of measuring equipment. Types of metrological checks. Organization and procedure of metrological verification.*	
6	***Topic 6International metrology organizations. Metrology in foreign countries*** *Lecture No. 6. International Metrology Organization. International Organization of Weights and Measures. International Organization of Legislative Metrology. Regional metrology organizations. Metrology in the countries of Western Europe. Metrology in the USA. Metrology in some countries of Eastern and Central Europe.* *Literature: [2] p.98-126; [3] pp. 96-124, [4] pp. 202-249, [14] pp. 108-136.* *Tasks on SRS Metrological examination of technical documentation. General provisions and tasks of metrological examination. Organization and procedure of metrological examination. Metrological examination of design documentation. Metrological examination of technological documentation.*	***2***
7	***Topic 7 Basic principles of measurement accuracy according to the theory of errors*** *Lectures No. 7-8. Best estimate ± accuracy. The difference between the measurement results. Comparison of two values: measured and theoretically known. Comparison of two measured values.* *Lecture No. 4. Comparison of two values: measured and theoretically known. Comparison of two measured values.* *Lecture No. 5. Relative errors. Significant figures in relative errors. Multiplication of two measured values* *Literature: [5] p.31-57; [7] pp. 23-54; [8] pp. 39-68.* *Tasks on SRS. Comparison of two values: measured and theoretically known. Comparison of two measured values.*	*4*
	In total	***18***

Practical training

In the system of professional training of students in this discipline, practical classes occupy 50% of the classroom load. They lay and form the foundations of students' qualifications. The content of these classes and the method of conducting them should ensure the development of the creative activity of the individual. They develop scientific thinking and the ability to use special terminology, allow you to check knowledge, therefore 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 students as creative workers.

The main tasks of the cycle of practical classesand laboratory workshops:

- *help students systematize, consolidate and deepen knowledge of a theoretical nature in the field of standardization, metrology and measurement accuracy;*
- *to teachtheir work with scientific and reference literature;*
- *to form skillsto learn independently, that is, to master the methods, methods and techniques of self-learning, self-development and self-control.*

No. z/p	Name of the subject of the practical session and list of main questions (a list of didactic support, references to the literature and tasks on the SRS)	Hour
1	General concepts of physical quantities. Systems of physical quantities. Clarification of the causes of errors. The main provisions of measurement accuracy. Solving problems for the purpose of general estimation of errors in the case of multiple measurements. Relative errors and significant figures. Literature: [5] p12-21; [7] pp. 6-14; [8] p. 16-23. Tasks on SRS. Solving problems for the purpose of general estimation of errors in the case of repeated measurements in laboratory conditions.	2
2	Errors in indirect measurements. Determining errors when using measurement results in sum, difference, multiplication and division operationsLiterature: [5] c. 49-64; [7] c.16-22. Tasks on SRS. Errors in indirect measurements in laboratory conditions.	4
3	Statistical analysis of random errors. Calculation of mean and standard deviation. Literature: [5] c.87-91, [7] c.34-43, [8] c. 49-54. Tasks on SRS. Calculation of mean and standard deviation in laboratory conditions.	4
4	Statistical analysis of random errors. Calculation of the standard deviation of the mean. Systematic errors. Solving tasks for sifting and combining measurement results. Literature: [5] c.92-101, [10] c.44-63, [13] c. 55-64. Tasks on SRS. Calculation of the standard deviation of the mean in laboratory conditions. Screening and combining of measurement results in laboratory conditions in laboratory conditions.	4
	Modular control works	2
	Test	2
	In total	18

7. Independent work of the student

Students' independent work takes up 70% of the course study time, including preparation for the test. The main task of students' independent work is the acquisition of scientific knowledge that is not included in the list of lecture questions, through a personal search for information, the formation of an active interest in a creative approach to educational work.

No. z/p	The name of the topic submitted for independent processing	Number of hours of SRS
	Chapter 1 Metrology and Fundamentals of Error Theory	
1	**Topic 1 The essence of metrological support and the basics of the theory of errors. Tasks and functions of metrological assurance of product conformity assessment.** SRS to topic 1 Principles and methods of measuring physical quantities. Literature: [1] p.10-23; [2] p.6-14, [3] p.7-19, [4] p.128-134. **Topic 2. Means of measuring technology (MET), classification of MT and their purpose** SRS to topic 2 Accuracy indicators and forms of presentation of measurement	62

	results. *Literature: [1] pp. 30-43; [2] pp. 16-34, [4] pp. 137-149, [14] pp. 28-44.* ***Topic 3 State metrological service of Ukraine*** *SRS to topic 3 Law on metrology: basic concepts and definitions.* ***Topic 4****Metrological assurance of unity and accuracy of measurements. State metrological control and supervision. Metrological service of the enterprise* *SRS to topic 4 State metrological service of the enterprise (organization).* *Literature: [2] p.48-66; [3] pp. 56-74, [4] pp. 166-184, [14] pp. 68-86.* ***Topic 5 Metrological attestation, verification and calibration of measuring equipment. Methods of verification of FTAs*** *SRS to topic 5 Metrological verification of measuring equipment. Types of metrological checks. Organization and procedure of metrological verification.* *Literature: [2] p.68-96; [3] pp. 76-94, [4] pp. 186-199, [14] pp. 88-106.* ***Topic 6 International metrology organizations. Metrology in foreign countries*** *SRS to topic 6 Metrological examination of technical documentation. General provisions and tasks of metrological examination. Organization and procedure of metrological examination. Metrological examination of design documentation. Metrological examination of technological documentation.* *Literature: [2] p.98-126; [3] pp. 96-124, [4] pp. 202-249, [14] pp. 108-136.* ***Topic 7 Basic principles of measurement accuracy according to the theory of errors*** *SRS to topic 7 Comparison of two values: measured and theoretically known. Comparison of two measured values.* *Literature: [5] p.31-57; [7] pp. 23-54; [8] pp. 39-68.*	
2	***Preparation for modular control works***	*4*
3	***Performing homework control work***	*12*
4	***Preparation for the test***	*6*
	Hours in general	*84*

Policy and control

8. Policy of academic discipline (educational component)

Rules of attending classes and behavior in classes

Master's students are obliged to take an active part in the educational process, not to be late for classes and not to miss them without a good reason, not to interfere with the teacher conducting classes, not to be distracted by activities unrelated to the educational process.

Rules for assigning incentive and penalty points

- *Incentive points can be awarded by the teacher exclusively for the performance of creative works in the discipline or additional completion of online specialized courses after agreement with the teacher and obtaining the appropriate certificate:*
  - https://prometheus.org.ua/,

- https://www.coursera.org/.

But their sum cannot exceed 10% of the rating scale.

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

Policy of deadlines and rescheduling

In the event of arrears from the academic discipline or any force majeure circumstances, master's students should contact the teacher in a timely manner through the available (provided by the teacher) communication channels to resolve problematic issues and agree on the algorithm of actions for practice.

Policy of academic integrity

Plagiarism and other forms of dishonest work are unacceptable. Plagiarism refers to the absence of references when using printed and electronic materials, quotes, opinions of other authors. Inadmissible tips and write-offs during the writing of control tasks, conducting classes; taking a test for another master's student; copying 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 Chapter 3 of the Code of Honor of the National Technical University of Ukraine "Ihor Sikorsky Kyiv Polytechnic Institute". More details:*https://kpi.ua/code

Policy of academic behavior and ethics

*Students should be tolerant, respect the opinion of others, formulate objections in the correct form, constructively support feedback during classes. Standards of ethical behavior of students and employees are defined in Chapter 2 of the Code of Honor of the National Technical University of Ukraine "Ihor Sikorskyi Kyiv Polytechnic Institute". More details:*https://kpi.ua/code

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

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

Semester	Training time		Distribution of study hours				Control measures		
	Credits	Acad. hours	Lectures	Practical	Lab. practice	SRS	MKR	DKR	Semester control
3	4.0	120	18	18	-	84	1	1	Test

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

Ratingmaster's studentfrom the credit module consists of points that he receives for:

– implementation and defense of practical tasks (4 works);

– writing two control papers (one MKR is divided into two one-hour control papers MKR-1 and MKR-2);

- performing homework control work;

Semester control is credit.

System of rating (weighted) points and evaluation criteria

The system of rating points and evaluation criteria:

Performing tasks in practical classes.

The weighted score for the first and second practical classes is 16 points each; in classes: third and fourth: 8 points each. The maximum number of points for all practical tasks is equal to: 16 points x 2 tasks + 8 points x 2 tasks = 48 points.

Criteria for evaluating the performance of a practical task:

Completeness and signs of task completion	*Points*	
	for 1 and 2	*for 3 and 4*
The task is fully completed	*16*	*8*
Minor flaws	*14-15*	*7*
Errors during task execution or protection	*12-13*	*6*
Late completion of the task, incomplete completion of the task and/or gross errors	*1-11*	*1-5*
Failure to complete the task	*0*	*0*

Writing modular control papers.

The weighted point for each modular control work is 16 points.

The maximum number of points for all test papers: 16 points x 2 papers = 32 points.

Criteria for evaluating the performance of control work:

Completeness and signs of task completion	***Points***
The task is fully completed	*16*
Minor flaws	*14-15*
Runtime errors	*12-13*
Incomplete completion of tasks and/or gross errors	*1-11*
Failure to perform work	*0*

Performing homework control work.

Homework is rated at a maximum of 20 points.

Evaluation criteria for homework performance:

Completeness and signs of task completion	***Points***
The work is fully completed	*20*
Minor flaws	*18-19*
Errors during tasks or protection	*13-17*
Late completion of tasks, incomplete completion of tasks and/or gross errors	*1-12*
Failure to complete the task	*0*

Thus, the rating semester scale from the credit module is:

$Rs = 2 \cdot 16 + 2 \cdot 8 + 2 \cdot 16 + 20 = 100$ points

According to the results of educational work in the first 7 weeks, the "ideal student" should score 32 points. At the first certification (8th week), the student receives "credited" if his current rating is at least 16 points.

According to the results of the educational work for 13 weeks of study, the "ideal student" should score 64 points. At the second certification (14th week), the student receives "credited" if his current rating is at least 32 points.

The maximum number of rating points is 100. To receive credit from the credit module "automatically", you need to have a rating of at least 60 points, complete and protect all practical tasks, and complete homework.

A necessary condition for admission to the credit is the completion and defense of all practical tasks, the completion of homework and a rating of at least 40% of the rating scale (R), i.e. 40 points.

Students who scored less than 0.6 R during the semester, as well as those who want to improve the overall rating, take a written credit test. At the same time, all the points they received during the semester are cancelled. Test tasks contain questions that refer to different sections of the credit module.

The control task of this paper consists of three questions. An approximate list of assessment questions is provided in Chapter 9. In this case, the sum of points for the assessment test is transferred to the final grade according to the table. The marks obtained by the student on the control work are final.

The credit control work is estimated at 100 points.

Each of the three test questions is valued at 33.33 points according to the evaluation system:

- *"excellent", complete answer (at least 90% of the required information) - 33-30 points;*
- *"good", sufficiently complete answer (at least 75% of the required information or minor inaccuracies) - 29-25 points;*
- *"satisfactory", incomplete answer (at least 60% of the required information and some errors) - 24-20 points;*
- *"unsatisfactory", unsatisfactory answer - 19-0 points.*

Table of conversion of rating points to grades.

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

9. Additional information on the discipline (educational component)

An approximate list of questions that are submitted for semester control:

1. *Analyze and evaluate the main concepts and definitions of the Law "On Metrology and Metrological Activities".*
2. *Give an assessment of the main provisions of state metrological control and supervision: name the types and purpose of its implementation, what it covers, what it is for, the objects and functions of state metrological control and supervision.*
3. *Give an assessment of measuring equipment (MET): definition of MT, types of MT, their list and definition by type of MT.*
4. *Give an assessment and definition of metrological attestation and calibration of measuring equipment.*
5. *Give an assessment and definition of metrological verification of measuring equipment.*
6. *To give an assessment of the methods of verification (calibration) of measuring equipment (MT), to characterize and name the verification schemes of the MT.*
7. *Analyze the main principles of the UkrSEPRO product certification system.*
8. *Give an assessment to the metrological service (MS) of Ukraine.*
9. *To analyze the purpose, functions and tasks of the International Organization of Weights and Measures (IOMV).*
10. *To evaluate and define the unity and accuracy of measurements.*
11. *To analyze and characterize the types of metrological verification of measuring equipment.*
12. *Give an assessment and characterize the metrological service of the enterprise.*
13. *To give an estimate and definition of a benchmark.*
14. *To evaluate the definition of metrology in its modern understanding.*

15. Give an assessment and definition of production certification.

16. Justify the concept and provide a formula for calculating the relative error.

17. To justify the concept of measurement accuracy through relative error.

18. To justify the use of the concept of relative error in the formula for calculating the error of obtaining measurement results.

19. Analyze and provide a rule for calculating the error of the sum and difference of two independent measured values.

20. Analyze the error calculation rules used when measuring independent measured quantities.

21. Analyze and provide the rule for calculating the error of the sum and the difference of values, the rule for the error of the product and division of the measurement results, as well as the rule for the product of the measurement result by an exact number.

22. To justify the use of the rule for calculating the error when raising the measured value to the power.

23. Analyze and provide a formula for estimating the error when using a satisfactory function of one variable in cases of indirect measurements.

24. To justify the use of the general formula for calculating errors in indirect measurements and the step-by-step method.

25. To justify the essence of the problem of combining the results of the experiment and to decide on the formulas for calculating the weighted average.

List of questions of modular control works

Modular control work (mkr: mkr1 + mkr2)

1. *Define metrology as a science.*
2. *What are the main tasks of metrology?*
3. *Show what problems the tasks of metrology are aimed at solving?*
4. *In accordance with tasks and functions, what types of metrology can be called?*
5. *In accordance with the law "On metrology and metrological activities" define the unity of measurements.*
6. *Name the main organization for ensuring the unity of measurements in Ukraine.*
7. *leadthat refers to departmental metrological services of Ukraine?*
8. *Define the measuring equipment.*
9. *List the types of measuring equipment?*
10. *Show why all FTAs are subject to mandatory state departmental verification?*
11. *leadWhat constitutes the basis of the state system of ensuring the unity of measurements?*
12. *Define what is called metrological support?*
13. *Bringat the expense of what is the unity of measurements achieved and to determine the unanimity of the FTA?*
14. *Show what constitutes the technical basis of metrological support?*
15. *leadWhat are the objects of State control and supervision?*
16. *Show what belongs to the functions of departmental metrological control?*
17. *Name the international metrological organizations that made and are making a significant contribution to solving the problems of the unity of measurements.*
18. *Analyze and provide the rule for calculating the error of the sum and the difference of values, the rule for the error of the product and division of the measurement results, as well as the rule for the product of the measurement result by an exact number.*

19. To justify the use of the rule for calculating the error when raising the measured value to the power.

20. Analyze and provide a formula for estimating the error when using a satisfactory function of one variable in cases of indirect measurements.

An approximate list of tasks for homework

1. Apply the formula for calculating the relative error (in percent) for five measurements:

- measured height = 5.03±0.04 m;

- measured time = 19.5±1 s;

*- measured charge = (-3.2±0.3) *10-19 K);*

*- measured wavelength = (0.56±0.07) *10-6 m);*

*- measured impulse = (3.27±0.04) *103 g*cm/s).*

2. Use the concept of measurement accuracy due to the relative error for the case, namely: suppose you need 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 up to 1 mm, and with the help of a microscope - up to 0.1 mm.

Is it possible to do this with a wooden ruler? With a microscope?

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

*It is necessary to calculate the value of the area of the strip S=a*в, 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 for calculating the error of the sum and the 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 the masses of these filled and then empty bottles and obtained as a result:

M1 - mass of the first cylinder and its contents = 540 ±10 g;

m1 = mass of the first empty cylinder = 72 ±1 g;

M2 = mass of the second cylinder and its contents = 940 ±20 g;

m2 = mass of the second empty cylinder = 97 ±1 g.

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 that are used when measuring independent measured values in the case of:

The specialist received the following measurement results:

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

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

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

6. Use the calculation rules: errors of the sum and difference of values, errors of the product and division of the measurement results, the product of the measurement result by an 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) (the numbers π and 2 have no error).*

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

After several time measurements, he finds:

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

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

Sin(ϑ) and error must be calculated.

9. To determine whether it is necessary to reject a questionable measurement result in the case of:

The specialist makes 14 measurements of the oscillation period of the generator and receives 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 Chauvenet criterion. Will he reject this result? How many results, similarly different from the mean as 12, should he expect?

10. Use the error estimation formula for the use of a satisfactory function of one variable in cases of indirect measurements: the angle ϑ was measured as θ *=20±3 degrees. This value is then used to calculate Cos* θ *.*

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

11. Determine the value of the χ2 criterion for a sample of 40 measurements x1, x2,... x40 of the length of the trajectory x of a bullet leaving 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

12. Calculate the average value and standard deviation of the results of ten measurements of one of the indicators characterizing paper quality (for example, paper smoothness): 86, 85, 84, 89, 86, 88, 88, 85, 83, 85.

Working program of the academic discipline (syllabus):

Compiled*associate professor, Ph.D., Ploskonos V.G.*

Approved*department ___E and TRP___ (protocol No. 14 dated 08.06.2022)*

Agreed*by the IHF Methodical Commission (protocol No. 10 dated 06.24.2022)*