Національний технічний університет України
«КИЇВСЬКИЙ ПОЛІТЕХНІЧНИЙ ІНСТИТУТ
імені ІГОРЯ СІКОРСЬКОГО»

Ecology and technology of plant polymers

Evaluating compliance and ensuring accuracy of measurements

Working program of the academic discipline (Syllabus)

Details of the academic discipline	
Level of higher education	***Second (master's)***
Branch of knowledge	*16 Chemical and bioengineering*
Specialty	***161 Chemical technologies and engineering***
Educational program	*Industrial ecology and resource-efficient clean technologies*
Discipline status	*Selective*
Form of education	*correspondence (day)/distance/mixed*
Year of training, semester	*1st year, spring semester*
Scope of the discipline	*5.0 credits (150 hours)*
Semester control/ control measures	*Exam*
Lessons schedule	*26 hours (20 hours of lectures + 6 hours 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/course/view.php?id=4395*

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 academic discipline will form the basis of understanding the main aspects of assessing the conformity of products, principles and methods of measuring physical quantities; assessments for the use of models of the state of complex technological systems of paper and cardboard production, the nature of errors that arise in the process of conducting experiments, the application of error theory methods for the analysis of random phenomena; calculation and calculation of the minimum possible errors of experimental research in laboratory and industrial conditions.

The subject of the educational discipline "Assessment of conformity and ensuring the accuracy of measurements"*– The main aspects of assessing the compliance of products with the requirements of regulations and state standards, labeling of products with signs of compliance with the requirements of DSTU and responsibility for violating the mandatory requirements of the standards; state control and supervision of compliance with the mandatory requirements of the standards. Basic definitions, principles and objects of standardization; the purpose and essence of standardization, the role of standardization in increasing the efficiency of the development of the national economy, international cooperation in the field of standardization; international standardization in ISO and IES. Measured physical quantities; principles and methods of measuring physical quantities; basic concepts of*

probability theory and statistics; measuring equipment, their classification and purpose; metrology and ensuring the unity and accuracy of measurements; metrological attestation of ZVT: methods of verification (calibration) of FTA; estimation of errors in the case of multiple direct measurements; relative errors; systematic errors, the problem of combining the results of different measurements; evaluation of error characteristics and measurement uncertainty calculation; comparative analysis of two approaches to determining the characteristics of measurement accuracy; identification of the characteristics of complex systems using the principles of self-organization and the topological method of analysis.

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 "Assessment of conformity and ensuring the accuracy of measurements"

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

– Ability to independently develop technological projects through creative application of existing and generation of new ideas;

– The ability to organize and manage chemical and technological processes in the conditions of industrial production and in research laboratories, taking into account social, economic and environmental aspects;

- Ability to demonstrate knowledge and own conclusions to specialists and non-specialists.

1.2. According to the requirements of the program of the educational discipline "Assessment of conformity and ensuring the accuracy of measurements", after mastering it, students must demonstrate the following learning outcomes:

- Search for the necessary information in scientific and technical literature, patents, databases, and other sources on chemical technology, processes and equipment for the production of chemical substances and materials based on them, systematize, and analyze and evaluate the relevant information;

- Be able to clearly and unambiguously convey professional knowledge, own justifications and conclusions to specialists and the general public, present own and collective technological, including innovative, projects;

- To be able to analyze, argue, make decisions based on the analysis of complex technological systems for the production of cardboard and paper products using computer technologies, the basic provisions of the theory of errors, the regularities of the normal law of the distribution of random variables and the corresponding mathematical apparatus of the theory of errors.

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"Evaluation of conformity and ensuring the accuracy of measurements" 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 "Evaluation of conformity and assurance of accuracy of measurements" is the basis that should ensuresolution 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. ENSURING ACCURACY OF MEASUREMENTS IN COMPLEX TECHNOLOGICAL SYSTEMS

Topic 1 Principles, methods and basic provisions of measurement accuracy

Principles and methods of measuring physical quantities. Basic concepts of probability theory and statistics. The inevitability of measurement errors and the importance of knowing the errors. Estimation of the error when counting from the scale. Estimation of errors in the case of multiple direct measurements.

Topic 2 Principles of modeling technological systems to determine the accuracy of measurements

The concept of modeling complex technological systems in engineering and scientific activities. Object of study. Types of optimization parameters and requirements for them. Model selection. Regression analysis is one of the process modeling methods. Basic terms and concepts of regression analysis. The method of least squares. Compilation of a system of normal equations (multiple regression). Statistical treatment of regression equations. Correlation analysis. Multiple linear correlation.

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 (MGUA). Criteria of maximum informativeness and noise resistance of the experiment. Methods of processing the results of experimental studies.

Topic 4 Fundamental aspects of ensuring the accuracy of measurements in complex technological systems

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.

Topic 5 Theoretical aspects of developing formulas for calculation in the process of multiple measurements with random deviations

Concept of random and systematic errors. Determination of the mean value and standard deviation. Standard deviation is like the error of a unit measurement. Standard deviation of the mean.

Formulas of sum and difference of measured values. Formulas for multiplying and dividing measured values, multiplying a measured value by an exact number. Formulas for raising the measured value to the power. Development of a general formula for calculating the sum, difference, product, and fraction of measured values. Formulas for calculating the accuracy of measurements using a satisfactory function of one variable. Formulas for calculating accuracy by the step-by-step method. Development of a generalized formula for calculating the accuracy of measurements in indirect measurements.

Topic 6 Theoretical aspects of the Law of normal distribution of a statistical quantity

Histograms and distribution of random variables. Limit distribution of random variables. The normal distribution of a random variable. Justification of error calculation formulas based on the law of normal distribution: standard deviation as a 68% confidence interval; average as the best grade.

Topic 7 Development and justification of the calculation of the confidence interval of measurements

Calculation formulas and justification of the confidence interval.

Topic 8 Development and substantiation of formulas for screening and combining the results of various measurements

The problem of sifting data. Chauvet's criterion. The problem of combining the results of different measurements. The concept of the χ2 criterion. Degrees of freedom and reduced value of χ2. Probabilities for χ2.

Topic 9 Comparative characteristics of the methodology for assessing the accuracy of measurements based on the concept of uncertainty

General concepts and definitions of the concept of uncertainty. An example of estimating error characteristics and calculating measurement uncertainty. Comparative analysis of two approaches to determining the characteristics of measurement accuracy.

CHAPTER 2. METROLOGICAL FUNDAMENTALS OF ENSURING ACCURACY OF MEASUREMENTS

Topic 1 The essence of metrological assurance of product conformity assessment. Tasks and functions of metrological assurance of measurement accuracy.

Systems of physical quantities and their units. Principles and methods of measuring physical

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

Topic 2 Basics of unity and accuracy of measurements to ensure conformity assessment of products

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

Topic 3 Ensuring the accuracy of measurements on the basis of metrological attestation, verification and calibration of measuring equipment

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 4 The role of international organizations in metrological assurance of measurement accuracy

International organizations for metrological support of measurements. International Organization of Weights and Measures. International organization of legislative metrological measurement assurance. Regional organizations for metrological support of measurements. Metrological support of measurements in the countries of Western Europe. Metrological support of measurements in the USA. Metrological support of measurements 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.

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, 2016. - 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.

4. Yermilova N.V., Kyslytsia S.G. "New sources of standardization and methodology" : Study guide / – Poltava: PoltNTU, 2017. - 141 p.

Additional literature

5. Law of Ukraine on metrology and metrological activities, No. 1765, Kyiv, June 15, 2004.

6. DSTU 3410-96 UkrSEPRO certification system. Substantive provisions.

7. 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, 2011.-220 p.

8. 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

Electronic resources from the course"Evaluation of conformity and ensuring the accuracy of measurements", namely:

- *credit module syllabus,*

- *methodical instructions for performing laboratory practicals and performing independent work*

located athttp://www.eco-paper.kpi.ua/for-student, as well as in the e-campus

Association of Ukrainian pulp and paper enterprises "UkrPapir" ***- ukrbim@naverex.kiev.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 "Assessment of conformity and ensuring the accuracy of measurements", the level of which is determined by the target setting for 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 metrology and measurement accuracy;

- 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 a 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 the list of main questions (list of didactic tools, references to the literature and tasks on the SRS)***	***Hour***
1	***CHAPTER 1. ENSURING ACCURACY OF MEASUREMENTS IN COMPLEX TECHNOLOGICAL SYSTEMS*** ***Topic 1 Principles, methods and basic provisions of measurement accuracy*** *Lecture No. 1. Measurable physical quantities. Principles and methods of measuring physical quantities. Basic concepts of probability theory and statistics.* *Literature: [5] pp. 12-19; [7] pp. 6-14; [8] pp. 5-17.* *Lecture No. 2. Mistakes are like mistakes. The inevitability of errors. How important it is to know mistakes. Estimation of the error when counting from the scale. Estimation of errors in the case of multiple direct measurements.* *Literature: [1] p.10-23; [2] p.6-14, [3] p.7-19, [4] p.128-134.* *Tasks on SRS. General provisions and classification of errors. Principles and methods of measuring physical quantities. Systems of physical quantities and their units. Accuracy indicators and forms of presentation of measurement results. General provisions and classification of errors. General provisions and classification of errors.*	*2*
2	***Topic 2 Principles of modeling technological systems to determine the accuracy of measurements*** *Lecture No. 3.The concept of modeling complex technological systems in engineering and scientific activities. Object of study. Types of optimization parameters and requirements for them. Model selection. Regression analysis is one of the process modeling methods. Basic terms and concepts of regression analysis. The method of least squares. Compilation of a system of normal equations (multiple regression). Statistical treatment of regression equations. Correlation analysis.*	*1*

	Literature: [4] c. 65-82. *Tasks on SRS. Multiple linear correlation.* ***Topic 3 Principles of mathematical self-organization of complex technological systems*** *Lecture No. 4.Principles of mathematical self-organization of complex technological systems. Method of group consideration of arguments (MGUA). Criteria of maximum informativeness and noise resistance of the experiment.* *Literature: [4] c. 88-102.* *Tasks on SRS. Methods of processing the results of experimental studies.*	
3	***Topic 4 Fundamental aspects of ensuring the accuracy of measurements in complex technological systems*** *Lecture No. 5. Best estimate ± accuracy. The difference between the measurement results. Comparison of two values: measured and theoretically known. Comparison of two measured values.* *Lecture No. 6. Comparison of two values: measured and theoretically known. Comparison of two measured values.* *Lecture No. 7. Relative errors. Significant figures are 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.*	*2*
4	***Topic 5 Theoretical aspects of developing formulas for calculation in the process of multiple measurements with random deviations*** *Lecture No. 8. Errors of the sum and difference of measured quantities. Multiplication and division of measured quantities. Multiplication of the measured value by an exact number. Raising the measured value to the power.* *Lecture No. 9. Independent errors when calculating the sum of measured values. Generalizing formulas for calculating the sum, difference, product, and fraction of measured values with independent errors.* *Lecture No. 10. Errors when using a satisfactory function of one variable. Step-by-step error calculation method. General formula for calculating errors in indirect measurements.* *Lecture No. 11. Random and systematic errors. Average value and standard deviation.* *Lecture No. 12. Standard deviation is the error of a unit measurement. Standard deviation of the mean. Systematic errors for experimental research in educational laboratories.* *Literature: [5] c.106-130, [10] c.54-72, [6] c. 88-101.* *Tasks on SRS. General information about errors in indirect measurements. Understanding errors in indirect measurements using examples. The principle of the arithmetic mean. Determination of the guarantee interval of measurement results. Summary of measurement errors. Errors of direct equal-precision measurements. Processing and assessment of the accuracy of exact measurements. Standard deviation of the mean in examples.* *Literature: [5] p.61-77; [7] pp. 63-85; [8] pp. 69-88.*	*3*
5	***Topic 6 Theoretical aspects of the Law of normal distribution of a statistical quantity*** *Lecture No. 13. Histograms and distribution of random variables. Limit distribution of random variables. The normal distribution of a random variable.* *Lecture #14. Standard deviation as 68% confidence interval. Justification of the average* $\bar{x}$ *as the best estimate and* σ *- the width of the marginal distribution.* *Lecture No. 15. Justification of the calculation of errors in indirect measurements. Justification of the standard deviation of the mean.* *Literature: [5] c. 148-172; [7] c. 78-95.* *Tasks on SRS. The law of probability distribution for multiple measurements.*	*3*

	Random variables. The use of elements of the theory of probabilities to the results of measurements. Repetition of tests - binomial distribution. Quadratic sum of errors and its justification. General case. Determination of the mean squared error. *Literature: [5] c.136-155, [3] c.54-72, [10] c. 88-101.*	
6	***Topic 7 Development and justification of the calculation of the confidence interval of measurements*** *Lecture No. 16. Calculation and justification of the confidence interval.* *Literature: [6] c. 123-155; [7] c. 108-123.* *Tasks on SRS. Confidence intervals. The required number of random variable measurements.*	*1*
7	***Topic 8 Development and substantiation of formulas for screening and combining the results of various measurements*** *Lecture No. 17. The problem of data screening. Chauvet's criterion. The problem of combining the results of different measurements.* *Literature: [5] c. 178-192; [13] c. 98-137.* *Tasks on SRS. The problem of data screening using the Chauvenet criterion on examples. The problem of combining the results of various measurements on examples.*	*1*
8	***Topic 9 Comparative characteristics of the methodology for assessing the accuracy of measurements based on the concept of uncertainty*** *Lecture No. 18. Concept of the χ2 criterion. Degrees of freedom and reduced value of χ2. Probabilities for χ2.* *Lecture No. 19. An example of the development of a typical method of performing measurements to determine the mass fraction of kaolin in an aqueous suspension.* *Lecture No. 20. General concepts and definitions of the concept of uncertainty. An example of estimating error characteristics and calculating measurement uncertainty. Comparative analysis of two approaches to determining the characteristics of measurement accuracy.* *Literature: [6] c. 168-182.* *Tasks on SRS. Linear correlation coefficient. quantitative criterion of significance r. Comparative analysis of two approaches to determining the characteristics of measurement accuracy* *Literature: [5] c. 198-222; [7] c. 218-141.*	*2*
9	***CHAPTER 2. METROLOGICAL FUNDAMENTALS OF ENSURING ACCURACY OF MEASUREMENTS*** ***Topic 1 The essence of metrological assurance of product conformity assessment. Tasks and functions of metrological assurance of measurement accuracy.*** *Lecture No. 21. Tasks and functions of metrology. 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.* *Lecture No. 22. Measuring equipment, their classification and purpose.*	*2*

	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.* *Lecture No. 23. 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.*	
10	***Topic 2 Basics of unity and accuracy of measurements to ensure conformity assessment of products*** *Lecture No. 24. 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).* ***Topic 3 Ensuring the accuracy of measurements on the basis of metrological attestation, verification and calibration of measuring equipment*** *Lecture No. 25. Metrological certification of measuring equipment. Verification 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.*	***2***
11	***Topic 4 The role of international organizations in metrological assurance of measurement accuracy*** *Lectures No. 26-27. International Organization for Metrology. 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.*	***1***
	In total	***20***

Practical training

In the system of professional training of students in this discipline, practical classes occupy 15% 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	***Practical lessons 1-2.*** *Basic provisions of measurement accuracy. Clarifying the causes of random and systematic errors. Solving a number of problems in order to estimate errors in the case of multiple measurements. Calculation of the relative error and learning the rule for determining significant figures in the final results.* *Literature: [5] p12-21; [7] pp. 6-14; [8] p. 16-23.* *Tasks on SRS. Clarifying the causes of errors and solving problems for the general assessment of errors in the case of multiple measurements.*	1
2	***Practical classes 3-4.*** *Solving problems in the case of indirect measurements. Clarification of the causes of errors due to the use of measurement results in sum, difference, multiplication and division operations* *Literature: [5] c. 49-64; [7] c.16-22.* *Tasks on SRS. Errors in indirect measurements in laboratory conditions.* ***MKR-1 on topics of sections 1-2 - 1 hour.***	1
3	***Practical lessons 5-6.*** *Clarification of causes and statistical analysis of random errors. Solving problems with the calculation of the mean and standard deviation.* *Literature: [5] c.87-91, [7] c.34-43, [8] c. 49-54.* *Tasks on SRS. Learning formulas for calculating the average and standard deviation in laboratory conditions.*	1
4	***Practical classes 7-8-9.*** *Learning the formula for using the Chauvenet criterion. Solving tasks to screen out "suspicious" measurement results.* *Learning formulas and solving problems for combining the results of measurements carried out in different testing laboratories to determine the average and total error.* *Literature: [5] c. 148-152; [8] c. 18-58.* *Tasks on SRS. Mastering the screening formula and combining measurement results in laboratory conditions.* ***MKR-2 on topics of chapter 3 - 1 hour.***	3
	In total	6

9. Independent work of the student

Independent work takes up 52% of the credit module study time, including exam preparation. The main task of students' independent work is the mastery of scientific knowledge in areas that are not included in the list of theoretical foundations through personal search for information, formation of active interest in a creative approach in educational work. In the process of independent work within the framework of the educational component, the student must learn to analyze modern methods of assessing the accuracy of metrological measurements and developing mathematical models.

No. z/p	The name of the topic submitted for independent processing	Number of hours of SRS
	CHAPTER 1. ENSURING ACCURACY OF MEASUREMENTS IN COMPLEX TECHNOLOGICAL SYSTEMS	
1	***Topic 1 Principles, methods and basic provisions of measurement accuracy.*** *Tasks on SRS. General provisions and classification of errors. Principles and methods of measuring physical quantities. Systems of physical quantities and their units. Accuracy indicators and forms of presentation of measurement results. General provisions and classification of errors. General provisions and classification of errors.* *Literature: [1] p.10-23; [2] p.6-14, [3] p.7-19, [4] p.128-134.* ***Topic 2 Principles of modeling technological systems to determine the accuracy of measurements*** *SRS to topic 2 Accuracy indicators and forms of presentation of measurement*	70

	results. *Literature: [1] pp. 30-43; [2] pp. 16-34, [4] pp. 137-149, [14] pp. 28-44.* ***Topic 3 Principles of mathematical self-organization of complex technological systems*** *SRS to topic 3 Methods of processing the results of experimental studies.* ***Topic 4 Fundamental aspects of ensuring the accuracy of measurements in complex technological systems*** *SRS to topic 4 Comparison of two values: measured and theoretically known. Comparison of two measured values* *Literature: [2] p.48-66; [3] pp. 56-74, [4] pp. 166-184, [14] pp. 68-86.* ***Topic 5 Theoretical aspects of developing formulas for calculation in the process of multiple measurements with random deviations*** *CRC to topic 5 General information about errors in indirect measurements. Understanding errors in indirect measurements using examples. The principle of the arithmetic mean.Determination of the guarantee interval of measurement results. Summary of measurement errors. Errors of direct equal-precision measurements. Processing and assessment of the accuracy of exact measurements. Standard deviation of the mean in examples.* *Literature: [2] p.68-96; [3] pp. 76-94, [4] pp. 186-199, [14] pp. 88-106.* ***Topic 6 Theoretical aspects of the Law of normal distribution of a statistical quantity*** *SRS to topic 6 The law of probability distribution for multiple measurements. Random variables. The use of elements of the theory of probabilities to the results of measurements. Repetition of tests - binomial distribution. Quadratic sum of errors and its justification. General case. Determination of the mean squared error.* *Literature: [2] p.98-126; [3] pp. 96-124, [4] pp. 202-249, [14] pp. 108-136.* ***Topic 7 Development and justification of the calculation of the confidence interval of measurements*** *SRS to topic 7. Confidence intervals. The required number of random variable measurements.* ***Topic 8 Development and substantiation of formulas for screening and combining the results of various measurements*** *SRS to topic 8.The problem of data screening using the Chauvenet criterion on examples. The problem of combining the results of various measurements on examples.* ***Topic 9 Comparative characteristics of the methodology for assessing the accuracy of measurements based on the concept of uncertainty*** *SRS to topic 9.Linear correlation coefficient. quantitative criterion of significance r. Comparative analysis of two approaches to determining the characteristics of measurement accuracy.*	
CHAPTER 2. METROLOGICAL FUNDAMENTALS OF ENSURING ACCURACY OF MEASUREMENTS		
2	***Topic 1 The essence of metrological assurance of product conformity assessment. Tasks and functions of metrological assurance of measurement accuracy.*** *SRS to topic 1 Principles and methods of measuring physical quantities. Accuracy indicators and forms of presentation of measurement results. Law on metrology: basic concepts and definitions.* *Literature: [5] pp. 12-19; [7] pp. 6-14; [8] pp. 5-17.* ***Topic 2 Basics of unity and accuracy of measurements to ensure conformity assessment of products*** *SRS to topic 2 State metrological service of the enterprise (organization).* *Literature: [5] pp. 21-29; [7] pp. 16-21; [8] pp. 25-37.* ***Topic 3 Ensuring the accuracy of measurements on the basis of metrological attestation, verification and calibration of measuring equipment*** *SRS to topic 3 Metrological verification of measuring equipment. Types of metrological checks. Organization and procedure of metrological verification.* *Literature: [5] p.31-57; [7] pp. 23-54; [8] pp. 39-68.* ***Topic 4 The role of international organizations in metrological assurance of measurement accuracy***	*31*

	SRS to topic 4 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: [5] p.61-77; [7] pp. 63-85; [8] pp. 69-88.*	
3	***Preparation for MKR***	*3*
4	*Preparation for the exam*	*20*
	Hours in general	*124*

Policy and control

10. Policy of academic discipline (educational component)

Rules of attending classes and behavior in classes

Attending classes is a mandatory component of the assessment. 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 actions 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 with the receipt of the appropriate certificate:*
- *https://www.coursera.org/learn/research-methods;*
- *https://ru.coursera.org/learn/metodologiya-nauchnyh-issledovanij-kotiki.*

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, students should contact the teacher through available (provided by the teacher) communication channels to resolve problematic issues and agree on an algorithm of actions for practice.

Policy of academic integrity

Plagiarism and other forms of dishonest work are unacceptable. Plagiarism includes the absence of references for the use of printed and electronic materials, quotes, opinions of other authors. Inadmissible tips and write-offs during writing tests, conducting classes; passing a test for another 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 opinions 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	5.0	150	20	6	-	124	1	–	exam

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

The rating from the credit module consists of points that he receives for work in practical classes and completion of MKR.

Semester control is an exam.

System of rating (weighted) points and evaluation criteria

The system of rating points and evaluation criteria:

Performance of tasks in practical classes.

Thus, the weighted score of the answer in the practical lesson (rn) = 4 points. The maximum number of points in all practical classes is equal to:

4 points x 9 = 36 points.

Weight score MKR-1 and MKR-2 (*rmkr) = 7 points each. The maximum number of points for all test papers is equal to: 7 points x 2 = 14 points.*

The maximum amount of points of the starting component during the semester is equal to:

(4 x 9) + (2 x 7) = 50 points

Under the condition of good preparation and active work in a practical lesson (or laboratory workshop) - 1 point. One or two best students in each practical lesson can be given 1 point as an incentive.

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

According to the results of educational work in the first 7 weeks, the "ideal student" should score 16 points. At the first certification (8th week), the student receives "passed" if his current rating is at least 0.5 x 16 = 8 points.

According to the results of 13 weeks, the "ideal student" should score 32 points. At the second certification (14th week), the student receives "credited" if his current rating is at least 0.5 x 32 = 16 points.

The size of the examination scale is RE = 50 points (50% of R)

Conditions for admission to the exam:*starting rating of at least 23 points (rc ≥ 23 points, at least 50% of RS).*

Examination assessment criteria

The exam ticket contains one theoretical question that has a weighting point of 30 and one practical task that has a weighting point of 25. The maximum number of points is 30 + 25 = 55 points.

The evaluation system of theoretical questions:

- *"excellent", complete answer (at least 90% of the required information) - 30-28 points;*
- *"good", sufficiently complete answer (at least 75% of the required information, or minor inaccuracies) - 23-22 points;*

– *"satisfactory", incomplete answer (at least 60% of the required information and some errors) - 18-16 points;*

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

Assessment system of practical classes*(or labs):*

– *"excellent", complete answer (at least 90% of the required information) - 23-22 points;*

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

– *"satisfactory", incomplete answer (at least 60% of the required information and some errors) - 15-13 points;*

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

The sum of starting points and points for answers to questions on the exam ticket is converted to the exam grade 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 not met	*not allowed*

11. Additional information on the discipline (educational component)

List of questions of modular control works

Modular control work (mcr-1)

1. Provide an unambiguous definition of the term: "FUNDAMENTALS OF EVALUATING THE ACCURACY OF MEASUREMENTS".
2. Provide an unambiguous definition of what the difference in measurement results is.
3. Define what relative error is? Give the relative error formula.
4. Give the rule of error of the product and division of the results of indirect measurements.
5. Give the error rule of the product of the result of indirect measurements by an exact number.
6. Bringgeneralizing formulas for calculating the product and fraction of measured values for independent errors.
7. Provide a brief description of the formula for calculating the error in a satisfactory function of one variable.
8. Explain how the confidence interval changes depending on the number of parallel experiments?
9. Provide an example of solving the problem of screening out abnormal results. Give the Chauvin criterion.
10. Give an example of solving the problem of combining the results of n measurements. Give the rule of association and formulas for calculating the average and total error.

Modular control work (mcr-2)

1. Provide a brief description of the main tasks that are set before the metrological support of measurements.
2. Provide a brief description of the solution to the problems posed in the tasks of metrological support of measurements.

3. In accordance with tasks and functions, what types of metrological measurement support can be named.
4. Based on the provisions of the law "On metrology and metrological activities" define the unity of measurements.
5. Give a definition ofperson of measuring equipment with guaranteed accuracy.
6. Provide a description of the types of measuring equipment.
7. Name the reasons for which all FTAs are subject to mandatory state departmental verification.
8. to describewhich forms the basis of the state system of ensuring the unity of measurements.
9. Provide a brief description of what achieves the unity of measurements and define the unanimity of the FTA.
10. Provide a brief description of the technical basis of metrological support.

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

1. *To substantiate the concept of measurement accuracy through absolute error.*
2. *To justify the use of the relative error in the error calculation formula when multiplying the measurement results.*
3. *To justify the rule for calculating the error used when measuring independent measured quantities.*
4. *To justify 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.*
5. *To justify the use of the rule for calculating the error when raising the measured value to the power.*
6. *Justify and provide a formula for estimating the error for using a satisfactory function of one variable in cases of indirect measurements.*
7. *To justify the use of the general formula for calculating errors in indirect measurements and the step-by-step method.*
8. *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.*
9. *Justify and provide the formula for calculating the standard deviation of the mean.*
10. *Justify and state the rule for calculating the error of the difference of measurement results.*
11. *Justify and provide formulas for calculating the value of the χ2 criterion.*
12. *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.*
13. *Justify and give a sequence of formulas for calculating a confidence interval.*
14. *To justify the schemes of using the Chauvenet criterion.*
15. *To analyze the error estimation formula for the use of a satisfactory function of one variable in cases of indirect measurements.*

An approximate list of tasks

1. Use the concept of measurement accuracy due to the relative error for the case, namely: suppose that 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?

2. 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.

3. 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.*

4. 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).*

5. 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 $h=(1/2)g*t^2$ *).*

After several time measurements, he finds:

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

6. 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.

*7. Use the general formula for calculating errors in indirect measurements and the "step by step" method, using the example of calculating a certain value c=a*v:*

a=10.0±0.5N; in=15±1 cm.

8. 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 can be said about the best estimate and margin of error based on his measurements?

9. Calculate the confidence interval in the case when the experimenter repeatedly measures g, the acceleration of free fall, and gets a result of 9.5 m/s2 and a standard deviation equal to 0.1.

If we assume that the results of his 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 much (or more) as the experimenter's result ?

Assuming that the experimenter did not actually make mistakes, could it be said that his experiment was probably affected by some undetected bias?

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

Can these two results be considered consistent?

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

11. Determine whether it is necessary to reject 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) It is necessary to calculate the average value $\overline{H}$ *and standard deviation* σ_H *of these results.*
b) If the specialist decides to use the Chauvin test, should he reject the result of 0.95 mm? It is necessary to argue the concession.

12. Use formulas for calculating the average value and standard deviation of the average 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 $\overline{x}$ *and standard deviation* σ_x*. Compare two options (with N and N-1) during the calculation* σ_x*.*

13. 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.*

14. 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?

15. 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.*

Working program of the academic discipline (syllabus):

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

Approved*department ___E and TRP___ (protocol No. 14 dated 18.05.2023)*

Agreed*Methodical commission of the IHF (protocol No. 10 dated 05/26/2023)*