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

Department of automation of energy systems

FUNDAMENTALS OF METROLOGY AND ELECTRICAL MEASUREMENTS

Syllabus of the educational component

Details of the academic discipline

Level of higher education	*First (undergraduate)*
Discipline	*14 "Electrical engineering"*
Specialty	*141 "Electric power engineering, electrical engineering and electromechanics"*
Educational program	*Electromechanical automation systems, electric drive and electric mobility ; Electric machines and devices*
Discipline status	*Normative educational components. Cycle of general training.*
Form of education	*Daytime*
Year of training, semester	*II year / autumn semester*
Scope of the discipline	*4 ECTS credits / 120 hours (36 hours of lectures; 18 hours of laboratory work)*
Semester control/ control measures	*Exam; MKR ; protection of laboratory works*
Class schedule	*http://roz.kpi.ua/* *1 lecture (2 hours) once a week;* *1 laboratory work (2 hours) once every 2 weeks*
Language of teaching	*Ukrainian*
Information about the head of the course / teachers	Lecturer: *candidate of technical sciences, Lavrenova Daryna Leonidivna, uran@fea.kpi.ua* Laboratory staff: *Lavrenova Daryna Leonidivna, uran@fea.kpi.ua ;* *Anastasia Oleksandrivna Tymokhina, a.planida@ukr.net ;* *Zakolodyazhny Volodymyr Vasyliovych, zakolodyazhnyv@gmail.com ;* *Hulyi Volodymyr Serhiyovych, vladimir_hulyi@ukr.net.*
Placement of the course	*https://do.ipo.kpi.ua/course/view.php?id=3883*

Program of educational discipline

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

The syllabus of the educational component "Fundamentals of metrology and electrical measurements" (OM) is compiled in accordance with the bachelor's training program in the field of knowledge 14 "Electrical engineering" with the specialty 141 "Electric power, electrical engineering and electromechanics", educational programs " Electromechanical systems of automation, electric drive and electric mobility ", " Electric machines and devices ".

The purpose of the academic discipline *is to form and consolidate the following competencies in students :*

K07. Ability to work in a team.

K14. The ability to solve complex specialized tasks and practical problems related to problems of metrology, electrical measurements, the operation of automatic control devices, relay protection and automation.

K19. Awareness of the need to increase the efficiency of electric power, electrotechnical and electromechanical equipment.

The subject of the educational discipline *is measurement methods, principles of construction of electrical measuring equipment and metrological support in the field of electric power.*

Program learning outcomes, the formation and improvement of which is aimed at the discipline:
PR02. To know and understand the theoretical foundations of metrology and electrical measurements, the principles of operation of automatic control devices, relay protection and automation, to have the skills to perform appropriate measurements and use these devices to solve professional tasks.
PR18. Be able to learn independently, acquire new knowledge and improve skills in working with modern equipment, measuring equipment and application software.

2. Prerequisites and postrequisites of the discipline

To successfully master the OM discipline , a student must possess the theoretical basis of the academic disciplines "Higher Mathematics", "General Physics", "Theoretical Basics of Electrical Engineering", "Electrotechnical Materials".

3. Content of the academic discipline

Chapter 1. Basic concepts of metrology.
Topic 1.1. Basic concepts of metrology.
Topic 1.2. Classification of measurement methods.
Topic 1.3. Measurement errors and uncertainties.

Section 2. Processing of measurement results, summation of errors and presentation of measurement results.
Topic 2.1. Presentation of measurement results.
Topic 2.2. Estimation of errors of direct measurements.
Topic 2.3. Evaluation of indirect measurement errors.
Topic 2.4. Evaluation of indirect measurement errors.
Topic 2.5. Methodical errors in the measurement of electrical quantities.

Chapter 3. Means of measuring electrical quantities.
Topic 3.1. Classification of ZVT and main characteristics of ZVT.
Topic 3.2. Verification and calibration of the HRT .

Chapter 4. Analog measuring devices.
Topic 4.1. Analogous ZV.
Topic 4.2 Shunts and additional supports.
Topic 4.3. ZVT of the magnetoelectric system.
Topic 4.4. ZVT of the electromagnetic system.
Topic 4.5. ZVT of the electrodynamic system.
Topic 4.6. ZVT of the ferrodynamic system.
Topic 4.7. ZVT of the electrostatic system.
Topic 4.8. ZVT of the induction system.
Topic 4.9. Electronic analog voltmeters.
Topic 4.10. Electron beam oscilloscopes.
Topic 4.11. Oscillographic methods of measuring signal parameters

Chapter 5. Digital measuring devices.
Topic 5.1. Digital measuring devices.
Topic 5.2. Analog -digital converters.
Topic 5.3. Errors of digital ZV.
Topic 5.4. Microprocessor multifunctional energy meter.

Chapter 6. Information and measurement systems.
Topic 6.1. Information and measurement systems.
Topic 6.2. Automatic system of control and accounting of energy on the PS.

Chapter 7. Measuring schemes.
Topic 7.1. Bridge measuring circuits.
Topic 7.2. Direct current bridges.
Topic 7.3. Alternating current bridges.
Topic 7.4. DC compensator.

Chapter 8. Power measurement in three-phase networks.
Topic 8.1. Power measurement in three-phase networks by wattmeter methods.
Topic 8.2. Analysis of the connection scheme of a 3-phase two-element meter.

Chapter 9. Current and voltage measuring transformers.
Topic 9.1. Characteristics of VTN and VTS.
Topic 9.2. Measuring current transformer.
Topic 9.3. Voltage measuring transformer.

4. Educational materials and resources

Basic literature:

1. *Lavrenova D.L. Fundamentals of metrology and electrical measurements [Electronic resource]: teaching . help for studies specialty 141 "Electric power engineering, electrical engineering and electromechanics". / D. L. Lavrenova, V. M. Khlistov ; KPI named after Igor Sikorsky. - 2nd edition, revised and supplemented - Electronic text data (1 file: 7.35 MB). – Kyiv: KPI named after Igor Sikorskyi, 2019. – 133 p. – Access mode: https://ela.kpi.ua/handle/123456789/30052*
2. *Lavrenova D.L. Fundamentals of metrology and electrical measurements: laboratory work (for students of all forms of education) [Electronic resource]: education . help for studies specialty 141 "Electric power engineering, electrical engineering and electromechanics", educational and professional programs "Power plants", "Non-traditional and renewable energy sources", "Electrical systems and networks", "Electrotechnical devices and electrotechnological complexes", "Management, protection and automation of energy systems" , "Electric machines and devices", "Electromechanical automation systems, electric drive and electric mobility " / D.L. Lavrenova , V.M. Khlystov - Kyiv: KPI named after Igor Sikorskyi, 2022. – 129 p. – Access mode: https://ela.kpi.ua/handle/123456789/48898*
3. *Fundamentals of metrology and electrical measurements: textbook / V. V. Kuharchuk, V. Yu. Kucheruk , Y. T. Volodarskyi, V. V. Grabko; Ministry of Education and Science, Youth and Sports of Ukraine, Vinnytsia National Technical University. Stereotype edition. – Kherson: Oldi -plus, 2020. – 537 p.*
4. *Kuharchuk V.V. Fundamentals of metrology and electrical measurements. Part I: summary of lectures / V. V. Kuharchuk – Vinnytsia: VNTU , 2020. – 148 p.*
5. *Nesterchuk D.M. Methods and means of measuring electrical and non-electrical quantities: a study guide / D.M. Nesterchuk , S.O. Kvitka , S.V. Galko . - Melitopol: "Tavrii State Agricultural Technological University", 2017. - 206 p.*

Additional literature:

6. *The distance course "Fundamentals of Metrology and Electrical Measurements" is posted on the distance learning platform "Sikorsky" - access mode: https://do.ipo.kpi.ua/course/view.php?id=3883.*
7. *Metrology. Terms and definitions. DSTU 2681-94. - [Valid from 01.01.1995] - K.: State Standard of Ukraine, 1994. - 72 p.*
8. *MLAnand . Electrical Measurements & Measuring Instruments . – sk kataria & sons , 2nd 2021 – 300 p.*
9. *Measurement . Journal of the International Measurement Confederation (IMEKO) - access mode: https://www.sciencedirect.com/journal/measurement.*

10. *Ruthard Minkner , Joachim Schmidt . The Technology of Instrument Transformers : Current and Voltage Measurement and Insulation Systems – Springer Vieweg ; 1st ed . 2022 edition (September 25, 2021) – 260 p.*

Educational content

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

The study of the discipline is aimed at students' assimilation of basic knowledge and skills in the field of electrical measurements and processing of measurement results. The main attention should be paid to the acquisition by students of the ability to use measuring equipment, to establish metrological characteristics of the FTA, to process the measurement results and to establish the measurement result in a standardized form.

Lecture classes

No. z/p	*Name of the topic of the lecture and list of main questions (list of didactic tools, links to information sources)*
1	*Topic 1.1. Basic concepts of metrology.* *Main issues : concept of physical quantity; tasks of metrology; international system (SI); measurement procedure; types of measurements.* *Topic 1.2. Classification of measurement methods.* *Main issues : definition and classification of measurement methods; balancing method; comparison method; substitution method; differential method.* *Literature : [1 , 4, 5]* *Supporting materials*: https://do.ipo.kpi.ua/course/view.php?id=3883*
2	*Topic 1.3. Measurement errors and uncertainties.* *Main issues : definition and classification of errors; absolute error; relative error; systematic error; random error; additive error; multiplicative error; static error; dynamic error; instrumental error; finding the error according to the class of accuracy of ZV; normalization of the additional error of the ZV; uncertainty of the measurement result.* *Literature : [1 , 2, 4, 5]* *Supporting materials*: https://do.ipo.kpi.ua/course/view.php?id=3883*
3	*Topic 2.1. Presentation of measurement results.* *Main questions : definition; rules for recording measurement results and presenting errors.* *Topic 2.2. Estimation of errors of direct measurements.* *Main questions : direct one-time measurements; direct multiple measurements.* *Topic 2.3. Evaluation of indirect measurement errors.* *Main issues : indirect one-time measurements; assessment of the systematic error of the indirect measurement result; estimation of the random error of the indirect measurement result.* *Literature : [1 , 2, 4]* *Supporting materials*: https://do.ipo.kpi.ua/course/view.php?id=3883*
4	*Topic 2.4. Evaluation of indirect measurement errors.* *Main issues : presentation of the results of indirect measurements; presenting the results of indirect measurements when the dependence is linear; presenting the results of indirect measurements when the dependence is non-linear.* *Topic 2.5. Methodical errors in the measurement of electrical quantities.* *Main questions : ammeter connection error; voltmeter connection error; wattmeter connection error.* *Literature : [1 , 2, 4]* *Supporting materials*: https://do.ipo.kpi.ua/course/view.php?id=3883*
5	*Topic 3.1. Classification of ZVT and main characteristics of ZVT.* *Main questions : classification of measuring equipment; main properties of ZV; characteristics that are necessary to obtain the measurement result; error characteristics Characteristics of sensitivity to*

	influential values; dynamic characteristics; interaction characteristics; non-informative parameters of the output signal ZV.. *Literature : [1 , 4, 5]* *Supporting materials*: https://do.ipo.kpi.ua/course/view.php?id=3883*
6	*Topic 3.2. Verification and calibration of the HRT .* *Main questions : definition; types of verification; the calibration procedure, when the accuracy class of the ZV is normalized by the cumulative error; calibration procedure, when the class of accuracy of the ZV is normalized by the relative error.* *Topic 4.1. Analogous ZV.* *Main questions : definition; structure; the moments operating in analog ZV; classification of measuring transducers.* *Topic 4.2 Shunts and additional supports.* *Main questions : expansion of measurement limits of analog ammeters and voltmeters Literature : [1 , 2, 4, 5]* *Supporting materials*: https://do.ipo.kpi.ua/course/view.php?id=3883*
7	*Topic 4.3. ZVT of the magnetoelectric system.* *Main questions : design and principle of operation of the ZVT of the magnetoelectric system; magnetoelectric ohmmeters.* *Topic 4.4. ZVT of the electromagnetic system.* *The main issues : the design and principle of operation of the VT electromagnetic system.* *Literature : [1 , 4, 5]* *Supporting materials*: https://do.ipo.kpi.ua/course/view.php?id=3883*
8	*Topic 4.5. ZVT of the electrodynamic system.* *Main issues : construction and principle of operation of the HRT of the electrodynamic system; electrodynamic ammeters and voltmeters; electrodynamic wattmeters; electrodynamic phase meter.* *Literature : [1 , 4, 5]* *Supporting materials*: https://do.ipo.kpi.ua/course/view.php?id=3883*
9	*Topic 4.6. ZVT of the ferrodynamic system.* *The main issues : the design and principle of operation of the ZVT of the ferrodynamic system.* *Topic 4.7. ZVT of the electrostatic system.* *Main issues : design and principle of operation of the HRT of the electrostatic system; electrostatic voltmeters.* *Literature : [1 , 5]* *Supporting materials*: https://do.ipo.kpi.ua/course/view.php?id=3883*
10	*Topic 4.8. ZVT of the induction system.* *Main issues : design and principle of operation of the HVT induction system; moments acting in induction coils; errors of induction HRTs ; schemes for connecting the active energy meter to a single-phase circuit; schemes for connecting the active energy meter to a three-phase circuit.* *Literature : [1 , 2, 5]* *Supporting materials*: https://do.ipo.kpi.ua/course/view.php?id=3883*
11	*Topic 4.9. Electronic analog voltmeters.* *Main questions : DC voltmeters; alternating current voltmeters .* *Topic 4.10. Electron beam oscilloscopes.* *Main questions : b widow of the electron beam tube; EPO structure ; internal synchronization mode; external synchronization mode; designation of "delay line"; main characteristics of oscilloscopes .* *Topic 4.11. Oscillographic methods of measuring signal parameters* *Main questions : amplitude and frequency measurement; frequency measurement by the circular sweep method; measurement of frequency by methods of Lissajous figures ; Measurement of the phase shift between signals by the Lissajous figure method ; linear sweep method for a 2-beam oscilloscope.* *Literature : [1 , 2, 5]*

	Supporting materials: https://do.ipo.kpi.ua/course/view.php?id=3883*
12	*Topic 5.1. Digital measuring devices.* *Main questions : definition; general structure; sampling and quantization.* *Topic 5.2. Analog -digital converters.* *Main issues : ADC classification ; ADC with time -pulse conversion; ADC with frequency-pulse conversion; ADC with decent balancing.* *Topic 5.3. Errors of digital ZV.* *Literature : [1 , 5]* *Supporting materials*: https://do.ipo.kpi.ua/course/view.php?id=3883*
13	*Topic 5.4. Microprocessor multifunctional energy meter.* *Main issues : structure; functional capabilities.* *Topic 6.1. Information and measurement systems.* *Main questions : definition; general principles of construction and functioning of the IBS .* *Topic 6.2. Automatic system of control and accounting of energy on the PS.* *Main issues : structure; principle of operation; survey methods of energy meters.* *Literature : [1 , 5]* *Supporting materials*: https://do.ipo.kpi.ua/course/view.php?id=3883*
14	*Topic 7.1. Bridge measuring circuits.* *Main issues : general structure and principle of action.* *Topic 7.2. Direct current bridges.* *Main questions : single direct current bridges - structure, principle of operation, sensitivity; double direct current bridges - structure, principle of operation, features.* *Literature : [1 , 2, 5]* *Supporting materials*: https://do.ipo.kpi.ua/course/view.php?id=3883*
15	*Topic 7.3. Alternating current bridges.* *Main issues : equilibrium conditions; construction of alternating current bridges for measuring various parameters of electrical elements; frequency-dependent and frequency-independent alternating current bridges; universal AC bridge for measuring inductance.* *Topic 7.4. DC compensator.* *Main issues : structure; principle of action; sensitivity; features; errors* *Literature : [1 , 2, 4, 5]* *Supporting materials*: https://do.ipo.kpi.ua/course/view.php?id=3883*
16	*Topic 8.1. Power measurement in three-phase networks by wattmeter methods.* *Main questions : Method of one wattmeter Method of two wattmeters The method of three wattmeters Conclusions on measurement of reactive power* *Literature : [1 , 2, 4, 5]* *Supporting materials*: https://do.ipo.kpi.ua/course/view.php?id=3883*
17	*Topic 8.2. Analysis of the connection scheme of a 3-phase two-element meter.* *Main questions : analysis of the scheme of the correct connection of the meter; analysis of some schemes of improper connection of the meter; conclusions* *Literature : [1 , 2, 4, 5]* *Supporting materials*: https://do.ipo.kpi.ua/course/view.php?id=3883*
18	*Topic 9.1. Characteristics of VTN and VTS .* *Main issues : appointment of VTN and VTS ; General characteristics of measuring transformers; schemes of connection of devices through VTS and VTN;* *Topic 9.2. Measuring current transformer.* *Main issues : the principle of operation of VTS ; errors* *Topic 9.3. Voltage measuring transformer.* *Main issues : principle of operation of VTN; errors* *Literature : [1, 2, 5]* *Supporting materials*: https://do.ipo.kpi.ua/course/view.php?id=3883*

** Supporting materials for lectures and practical classes are available for download only to applicants who are registered for the distance course "Fundamentals of metrology and electrical measurements" on the distance learning platform "Sikorsky" [6].*

practical classes *.*

Laboratory work

The purpose of the cycle of laboratory work is the practical implementation of measurement methods, the study of the technical characteristics of measurement tools and the acquisition of skills in their practical application. In laboratory classes, students should gain practical experience in using measuring equipment and measurement methods, as well as learn how to measure and calculate the parameters of electric circuits. In defense of the laboratory work, the student is asked to solve a problem based on the method of calculations for the laboratory work.

During laboratory work (the first half of the classroom session), students must reproduce the corresponding "Procedure of work" specified in the methodical instructions. Preparation for laboratory work, preparation of reports and preparation for the defense are provided within the scope of the student's independent work. The defense of laboratory work takes place in laboratory classes (the second half of the classroom class).

Laboratory work

No. z/p	*List of laboratory works*	*Number of aud . hours*
1	*Measurement of parameters of single-phase electric circuit modes.* *The purpose of the work : studying the construction, principle of operation and rules for turning on analog devices for measuring current, voltage, active power and power factor in a single-phase circuit; to study the methods and acquire practical skills of measurement and analysis of the parameters of the single-phase circuit mode.*	*2*
2	*Measurement of electrical equipment parameters on direct current.* *Purpose of the work : study of direct current bridges and means of measuring the parameters of electrical equipment on direct current; acquiring practical skills in using appropriate measuring tools.*	*2*
3	*Application of measuring current and voltage transformers for measuring parameters of the mode of single- and three-phase circuits.* *The purpose of the work : studying the scheme of turning on devices through current and voltage measuring transformers and acquiring practical skills in drawing up schemes and carrying out a set of measurements.*	*2*
4	*Measurement of active power in three-phase current circuits.* *The purpose of the work : the study of methods of measuring active power in three-phase current circuits with uniform and uneven loads, as well as the study of the effect of changing the phase shift angle on the readings of 2 wattmeters.*	*2*
5	*Measurement of electric circuit parameters with an electron-beam oscilloscope.* *The purpose of the work : study of the construction, principle of operation of the electronic oscilloscope, familiarization with the method of electrical measurements and acquisition of practical skills of its application.*	*2*
6	*Measurement of losses in sheet electrical steel by the wattmeter method.* *The purpose of the work : study of the wattmeter method of measuring losses in sheet electrical steel.*	*2*
7	*MKR*	*2*

8	*Credit classes (certification)*	*4*
IN GENERAL		*18*

Modular control work (MCR)

The purpose of the MKR is to consolidate and verify theoretical knowledge from the educational component, students to acquire practical skills in finding and recording the results of various types of measurement and calculating the parameters of measuring equipment.

MKR is divided into 3 parts (30 minutes each) and is aimed at consolidating understanding of theoretical and practical material and preparing for the exam. The task for each MKR consists of theoretical questions and a practical task. Examples of problems are considered in lectures and laboratory classes.

6. Student's independent work

Independent work of students consists in

- *performing laboratory work (students should independently study the materials presented in the theoretical information of the methodological instructions for laboratory work; 1 hour is recommended for the preparation of each laboratory work),*
- *preparation of reports on laboratory work (2 hours are recommended for the completion of the report and preparation for the defense of each laboratory work),*
- *thorough preparation for thematic modular control papers and the exam (6 hours of preparation is recommended).*

Policy and control

7. Policy of academic discipline (educational component)

The system of requirements that the teacher sets before the student:

Rules for attending classes.

It is forbidden to assess the presence or absence of the winner in the classroom session, including the awarding of incentive or penalty points. According to the RSO of this discipline, points are awarded for the corresponding types of educational activity in lectures and laboratory classes.

Attendance of laboratory classes by students is mandatory. If the student has a document that justifies the impossibility of his presence at the laboratory work, he is given the opportunity to complete the work according to the schedule agreed with the teacher.

Rules of behavior in classes.

The student has the opportunity to receive points for the appropriate types of educational activity in lectures and laboratory classes, provided for by the RSO of the discipline. During the execution of modular control works, it is allowed to use sources of information in paper or electronic form, but it is forbidden to consult with third parties. For non-independent performance of the task (after consultation with other persons or a collective meeting), all students receive penalty points in accordance with the RSO of the discipline.

During the exam, it is forbidden to use any sources of information and to consult/consult with outsiders.

Policy of deadlines and rescheduling.

If a student did not pass or did not appear at the MKR (without a good reason), his result is evaluated at 0 points. Recompilation of MKR results is not provided for. If the student has a document that justifies the impossibility of passing the modular control work on time, he is given the opportunity to complete the work remotely within a week after he appears in class.

Academic Integrity Policy.

The Code of Honor of the National Technical University of Ukraine "Ihor Sikorskyi Kyiv Polytechnic Institute" (https://kpi.ua/files/honorcode.pdf) establishes general moral principles, rules of ethical behavior of persons and provides for a policy of academic integrity for persons working and studying at the university, which they should be guided by in their activities, including when studying and preparing control measures in the discipline "Fundamentals of Metrology and Electrical Measurements".

When using digital means of communication with the teacher (mobile communication, e-mail, correspondence on forums and social networks, etc.), it is necessary to observe generally accepted ethical norms, in particular, to be polite and limit communication to the working hours of the teacher.

Penalty and incentive points

Task type	***Number of points***
non-independent performance of the MKR task	*- 1 point for each "collective meeting"*
timely (according to the class schedule) defense of all laboratory work	*+ 7 points*

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

Current control: *it is carried out based on the results of the student's work in laboratory classes and the performance of modular control works.*

Task type	***Weight score***	***Number***	***Total score***
Work in laboratory classes (creative task or calculation task)	*7*	*6*	*42*
Execution of MKR	*6*	*3*	*18*
Exam	*40*	*1*	*40*
In total			*100*

Criteria for evaluating laboratory works:

The maximum number of points awarded for one laboratory work is a total of 7 points. They consist of the following assessments:

- *for the performance of laboratory work (positive input control) and proper preparation of the report (in accordance with the requirements specified in the methodical instructions) - 0... 3 points,*
- *for correctness and completeness of calculations - 0... 1 point,*
- *for the answer to a theoretical question - 0... 1.5 points ,*
- *for the solution of the problem in defense - 0 ... 1.5 points.*

MKR evaluation criteria :

Each MKR consists of 2 theoretical questions and 1 practical problem. The maximum number of points for the performance of each MKR is 6 points. They consist of grades for each task.

Evaluation criteria for a theoretical question:

- *complete answer to the question - 1.5 points;*
- *incomplete answer to the question, or there are significant errors in the answer - 0.6...1.4 points;*
- *the answer is unsatisfactory - 0.5 points;*
- *no answer - 0 points.*

Evaluation criteria for practical tasks:

- *solution complete - 3 points;*
- *the solution is not complete, or there are minor errors in the solution - 2.0...2.9 points;*
- *the solution is not complete, there are minor errors in the solution - 0.6...1.9 points;*
- *the solution is not complete, there are significant errors in the solution - 0.5 points;*
- *no solution - 0 points.*

Calendar control: *carried out twice a semester (attestation) as a monitoring of the current state of meeting the requirements of the syllabus.*

Intermediate certification	*The minimum number of protected laboratory works to obtain a positive attestation*	*The minimum number of points to receive a positive attestation*
AND	*3*	*12*
II	*6*	*25*

Semester control: *assessment*

At the end of the semester, students must complete an examination paper. The examination paper consists of 2 theoretical questions and 2 practical problems. The maximum score that a student can receive for an examination paper is 40 points. Points for the exam work are added to the points earned during the semester when performing laboratory work and modular control work.

Evaluation criteria for a theoretical question:

- *complete answer to the question - 9.5...10 points;*
- *incomplete answer to the question - 7.5...9.4 points;*
- *incomplete answer to the question, or there are significant errors in the answer - 6...7.4 points;*
- *the answer is unsatisfactory - 1...5.9 points;*
- *no answer - 0 points.*

Evaluation criteria for practical tasks:

- *solution complete - 9.5...10 points;*
- *the solution is not complete, or there are minor errors in the solution - 7.5...9.4 points;*
- *the solution is not complete, there are minor errors in the solution - 6...7.4 points;*
- *the solution is not complete, there are significant errors in the solution - 1...5.9 points;*
- *no solution - 0 points.*

Table of correspondence of rating points to grades on the university scale:

Number of points	***Rating***
95-100	*Perfectly*
85-94	*Very good*
75-84	*Good*
65-74	*Satisfactorily*
60-64	*Enough*
Less than 60	*Unsatisfactorily*
Admission conditions not met	*Not allowed*

Conditions for admission to semester control: *performance and defense of 6 laboratory works. Students who received less than 20 points in the rating during the semester must complete additional control work.*

9. Additional information on the discipline (educational component)

Certificates of completion of distance or online courses on the relevant subject may be credited subject to compliance with the requirements specified in Order No. 7-177 dated 01.10.2020 "On approval of the provision on recognition in KPI named after Igor Sikorskyi of learning outcomes acquired in non-formal/ informal education".

Working program of the academic discipline (syllabus):

Compiled by Daryna Leonidovna Lavrenova , senior lecturer of the AE department , Ph.D.

Approved by the AE department (protocol No. 14 dated 06/27/2024)

Agreed by the Methodical Commission of the faculty (protocol No from 2024 year)