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

Department of Applied Radio Electronics

[RE-346] DESIGN AND TECHNOLOGIES FOR THE PRODUCTION OF INTELLIGENT RADIO ELECTRONIC EQUIPMENT

Curriculum of the academic discipline (Syllabus)

Course details

Level of higher education	First (bachelor's)
Field of knowledge	17 - Electronics, Automation, and Electronic Communications
Specialization	172 - Electronic Communications and Radio Engineering
Educational program	Intelligent technologies of radio electronics
Discipline status	Regulatory
Form of higher education	Full-time
Year of training, semester	4th year, fall semester
Scope of the discipline	7 credits (Lectures 72 hours, Practical work 36 hours, Laboratory work 18 hours, Independent work 84 hours)
Semester control/control measures	Exam
Class schedule	https://schedule.kpi.ua
Language of instruction	Ukrainian
Information about the course coordinator/teachers	Lecturer: Novosad A. A., Practical instructor: Golovnya V. M.,
Course location	

Curriculum

1. *Description of the academic discipline, its purpose, subject matter, and learning outcomes*

Modern intellectual radio-electronic technology combines advanced system engineering, circuit engineering, and software solutions that ensure its functionality, adaptability, and reliability. The process of designing such equipment requires a comprehensive approach, taking into account

conflicting requirements for design, operating conditions, material production constraints, and standardization requirements.

The aim of the discipline is to develop a systematic approach to the design process of radio-electronic equipment, including the analysis and synthesis of design solutions, the creation of physical (thermal, humidity, mechanical, electrodynamic, etc.) and mathematical models, as well as the calculation of basic design parameters, taking into account a dialectical approach to solving design problems.

The subject of study is the patterns of design, technology of creation and production of intellectual radio-electronic equipment. Particular attention is paid to the influence of the purpose, installation object, principle of operation and operating conditions on design decisions.

One of the key tasks of the discipline is to develop skills in the development and preparation of textual and graphic design documentation in accordance with current standards.
The discipline also involves mastering design technologies and methods, using modern CAD systems, principles of design optimization, and ensuring manufacturability.

As a result of studying the discipline, the applicant acquires the following competencies:

General competencies

GC 01 Ability to think abstractly, analyze, and synthesize

GC 02 Ability to apply knowledge in practical situations.

GC 04 Knowledge and understanding of the subject area and understanding of professional

activity.

GC 08 Ability to identify, set, and solve problems.

Professional competencies

PC 01 Ability to understand the essence and significance of information in the development of modern information society

PC 02 Ability to solve standard tasks of professional activity based on information and bibliographic culture using information and communication technologies and taking into account the basic requirements of information security.

PC 04 Ability to perform computer modeling of devices, systems, and processes using universal application software packages

PC 05 Ability to use regulatory and legal documentation related to information and telecommunications networks, telecommunications and radio engineering systems (laws of Ukraine, technical regulations, international and national standards, recommendations of the International Telecommunication Union, etc.) to solve professional tasks

PC 06 Ability to perform instrumental measurements in information and telecommunications networks, telecommunications and radio engineering systems.

PC 08. Willingness to promote the implementation of promising technologies and standards.

PC 10 Ability to install, debug, configure, adjust, test, and commission telecommunications and radio engineering structures, facilities, and equipment.

PC 11 Ability to compile regulatory documentation (instructions) for the operational and technical maintenance of information and telecommunications networks, telecommunications and radio engineering systems, as well as test programs.

PC 14 Willingness to study scientific and technical information, domestic and foreign experience on the subject of investment (or other) projects for telecommunications and radio engineering equipment

PC 16 Ability to apply standard calculation methods in the design of telecommunications and radio engineering devices and systems

PC 17 Ability to participate in design and technological preparation, implementation in production, and support of radio-electronic equipment production

PC 18 Ability to assess the place and advantages of introducing elements of intelligent technologies and intelligent radio electronics into various fields of human activity

PC 21 Ability to take a comprehensive approach to the development of radio-electronic equipment

PC 22 Ability to select and critically evaluate and choose technical solutions at all stages of the development and design of radio-electronic equipment using intelligent technologies

PC 23 Ability to select and apply specialized software tools for simulation modeling and design of radio-electronic equipment

PC 25 Ability to reasonably select CAD for analysis, calculation, optimization of the output characteristics of mathematical and circuit models of analog and digital devices depending on the frequency range, taking into account external factors, use Internet information resources to obtain mathematical and design models of radio components from manufacturers based on an assessment of the characteristics of information transmission in radio networks

Program learning outcomes

PLO 01 Analyze and make informed decisions when solving specialized tasks and practical problems in telecommunications and radio engineering, which are characterized by complexity and incomplete certainty of conditions

PLO 02 Apply the results of personal search and analysis of information to solve qualitative and quantitative problems of a similar nature in information and communication networks, telecommunications and radio engineering systems;

PLO 04 Explain the results obtained from measurements in terms of their significance and relate them to the relevant theory.

PLO 07 Competently apply terminology in the field of telecommunications and radio engineering

PLO 14 Application of understanding of the basic properties of the component base to ensure the quality and reliability of telecommunications, radio engineering systems and devices.

PLO 15 Application of understanding of means of automation of design and technical operation of telecommunications and radio engineering systems in professional activity.

PLO 16 Application of understanding of the basics of metrology and standardization in the field of telecommunications and radio engineering in professional activities.

PLO 18 Find, evaluate, and use information from various sources necessary for solving professional tasks, including reproducing information through electronic search.

PLO 20 Explain the principles of construction and operation of hardware and software complexes of control and maintenance systems for the development, analysis, and operation of information and telecommunications networks, telecommunications, and radio engineering systems.

PLO 22 Monitor the technical condition of information and communication networks, telecommunications and radio engineering systems during their technical operation in order to identify deterioration in performance or failures, and systematically record this by means of documentation.

PLO 26 Design and implement elements of intelligent technologies using software-configurable hardware

PLO 28 Apply methods and means of influencing the parameters of the physical environment

PLO 29 Select the configuration, structure, main components, and elements of radio-electronic equipment depending on its purpose

PLO 30 Apply a comprehensive approach to the design of telecommunications and radio-electronic equipment

PLO 31 Apply the basics of designing radio-electronic equipment for intelligent systems and the latest component base and materials when designing radio-electronic equipment for intelligent systems

PLO 32 Apply the basic principles of diagnostics, control, and testing of radio-electronic equipment at the main stages of production using intelligent technologies

2. *Prerequisites and post-requisites of the discipline (place in the structural-logical scheme of training under the relevant educational program)*

The discipline is based on knowledge gained from studying the following

disciplines: • Programmable tools in intelligent radio-electronic

technology
• Occupational safety and civil protection

The study of this discipline is based on

• Communication means in intelligent radio-electronic systems. • Pre-diploma internship

3. *Contents of the academic discipline*

Section 1. Methodological foundations of intelligent radio-electronic equipment design

1.1. Classification, purpose, and features of intelligent radio-electronic equipment
1.2. Stages of the life cycle of radio-electronic equipment. Organization of design and engineering work
1.3. Principles of construction and engineering design of intelligent systems
1.4. Interconnection of design with circuit engineering, programming, EMC, and production technology

Section 2. Reliability of intelligent radio-electronic equipment

2.1. Key reliability indicators
2.2. Methods of ensuring and improving reliability
2.3. Calculation of key reliability indicators

Section 3. Electromagnetic compatibility of electronic equipment

3.1. Sources and types of electromagnetic interference
3.2. EMC-conscious layout
3.3. Designing common buses and grounding in radio electronic equipment
3.4. Shielding
3.5. Circuit design methods for EMC
3.6. Designing signal and power lines with EMC in mind
3.7. EMC modeling

Section 4. Ensuring thermal conditions in the design of electronic equipment

4.1. Physical principles of heat transfer in electronic equipment
4.2. Thermal models of electronic equipment. Predicting temperature conditions
4.3. Heat dissipation methods
4.4. Thermal optimization of design in CAD

Section 5. Moisture protection

5.1. The effect of humidity on the parameters and reliability of electronic equipment
5.2. Methods of moisture protection

Section 6. Ensuring the mechanical stability of REA structures

1.1. Mechanical loads: vibrations, shocks, linear accelerations, acoustic pressure
1.2. Structural strength of elements and fasteners
1.3. Methods of protection against mechanical loads
1.4. Dynamic modeling and testing of electronic equipment for stability

Section 7. Technologies for the production of intelligent REA

7.1. Methods of mechanical processing and manufacturing of housing parts
7.2. Technologies for assembling, connecting, and mounting elements
7.3. Methods of automated and manual assembly of electronic equipment blocks
7.4. Control, diagnostics, and testing of electronic equipment

Chapter 8. Digital technologies and Industry 4.0 in the design and manufacture of radio-electronic equipment

8.1. The concept of Industry 4.0 and its impact on the design of radio-electronic equipment
8.2. Digital manufacturing: digital twin and digital flow
8.3. Digital manufacturing tools and platforms
8.4. Augmented and virtual reality in the design and maintenance of electronic equipment

4. *Training materials and resources*

1. Physical and theoretical foundations of radio-electronic equipment design [Electronic resource]: a textbook for bachelor's degree students in the educational program "Information and computing means of radio-electronic systems" specialty 172
"Telecommunications and Radio Engineering" / Igor Sikorsky Kyiv Polytechnic Institute; compiled by: V.
G. Gubar, I. O. Adamenko. – Electronic text data (1 file: 10.2 MB). – Kyiv: Igor Sikorsky Kyiv Polytechnic Institute, 2020. – 221 p. https://ela.kpi.ua/handle/123456789/34778

2. Lecture notes on the discipline "Fundamentals of Electronic Equipment Design" for students majoring in 172 "Telecommunications and Radio Engineering" (educational programs "Radio Electronic Devices and Means" and "Intelligent Technologies of Microsystem Radio Electronic Engineering") of all forms of training / Compiled by: Pospieva I.E., Furmanova N.I., – Zaporizhia: ZNTU, 2018. – 78 p.

3. Design and production technology of telecommunications systems: Lecture notes for students majoring in 172 "Telecommunications and Radio Engineering" of all forms of training/ Yevsina N.O., Dudnik A.V. - Kharkiv: NTU "KhPI", 2022. - 36 p.

4. O.L. Korenivska, V.B. Benedytskyi. Theory of reliability, operation, and repair of radio-electronic and telecommunications equipment. Textbook. – Zhytomyr: Zhytomyr Polytechnic State University, 2020. – 180 p.

5. Bondarenko, Igor Mykolayovych. Design of Semiconductor Devices and Integrated Circuits: Textbook for Students Majoring in Micro- and Nanosystem Engineering and Electronics / I.M. Bondarenko, O.V. Borodin, V.P. Karnauchenko; Ministry of Education and Science of Ukraine, Kharkiv National University of Radio Electronics. Kharkiv: KNURE, 2019. - 174 p. https://opac.kpi.ua/F/?func=direct&doc_number=000603218&local_base=KPI01

6. Gotra, Zenon Yuriyovych. Electronic Engineering Technology: Textbook for Students of the Basic Direction "Electronics": in 2 volumes / Z.Y. Gotra; Ministry of Education and Science of Ukraine, National University "Lviv Polytechnic". Lviv: Publishing House of NU "Lviv Polytechnic", 2010. https://opac.kpi.ua/F/?func=direct&doc_number=000350523&local_base=KPI01

7. Zinkovsky, Yuriy Frantsevich. Computer circuit modeling of radio electronics elements: textbook for students of higher educational institutions /Y.F. Zinkovsky, A.V. Koval; Ministry of Education and Science, Youth and Sports of Ukraine, National Transport University.Kyiv: National Transport University, 2013 - Vol. 1, Part 1: Passive element base; Part 2: Filters. -- 2013. -- 348 p.https://opac.kpi.ua/F/?func=direct&doc_number=000350178&local_base=KPI01

8. Bobalo, Yuriy Yaroslavovych. Quality and reliability of radio-electronic equipment. Elements of theory and methods of assurance: monograph /Y.Y. Bobalo, L.A. Nedostup, M.D. Kiselichnik; edited by L.A. Nedostup; Ministry of Education and Science of Ukraine, Lviv Polytechnic National University. Lviv: Lviv Polytechnic Publishing House, 2013. - 196 https://opac.kpi.ua/F/?func=direct&doc_number=000640841&local_base=KPI01

9. Mirskikh, Georgy Alexandrovich. Control of parameters during the design, manufacture, and operation of radio-electronic equipment: textbook for students of higher educational institutions majoring in "Manufacture of Electronic Devices" and "Electronic Construction of Equipment" /G.O. Mirskikh, N.M. Rudenko; NTUU "KPI". K.: NTUU "KPI", 2009. - 140 https://opac.kpi.ua/F/?func=direct&doc_number=000241759&local_base=KPI01

10. Domnich V. I. Thermal and moisture protection of electronic devices: [textbook for students of radio engineering specialties of higher educational institutions] / V. I. Domnich, Yu. F. Zinkovsky. - 124 p.

11 Bilyk I. I., Rudenkyi S. O. Technology of coating application and their properties: textbook. – 2023. – 120 p.https://ela.kpi.ua/bitstream/123456789/56927/1/Tekhnolohiia_nanesennia_pokryttiv_ta_ yikh_vlastyvosti.pdf

12. Schwab K. The Fourth Industrial Revolution: what it means, how to respond. URL:https://www.foreignaffairs.com/articles/2015-12-12/fourth-industrial-revolution

13. Voytko, S. V. Project and Startup Management in Industry 4.0: Textbook / S. V. Voytko // Kyiv - Igor Sikorsky Kyiv Polytechnic Institute, Polytechnika Publishing House, 2019 - 200 p.

Educational content

5. *Methodology for mastering the academic discipline (educational component)*

Lecture material is presented in the order specified in accordance with the sections, which provides a logical structure for designing an intellectual device from an electrical schematic diagram to a finished device. Practical classes are conducted for each of the topics to reinforce the theoretical material with practical skills in calculating and modeling the components of the device. Knowledge of the lecture material is required to complete each laboratory assignment. The entire course is divided into 8 topics. Laboratory cover all lecture topics and supplement them.

Lectures

Topic 1. Methodological foundations of intelligent radio-electronic equipment design

Lecture 1. Classification, purpose, and features of intelligent radio-electronic equipment
Lecture 2. Stages of the life cycle of radio-electronic equipment. Organization of design and engineering work
Lecture 3. Principles of construction and engineering design of intelligent systems
Lecture 4. Interconnection of design with circuit engineering, programming, EMC, and production technology

Topic 2. Reliability of intelligent electronic equipment

Lecture 5. Key reliability indicators
Lecture 6. Methods of ensuring and improving reliability
Lectures 7-8. Calculation of key reliability indicators

Topic 3. Electromagnetic compatibility of electronic equipment

Lecture 9. Sources and types of electromagnetic interference
Lecture 10. Layout with EMC in mind
Lecture 11. Designing common buses and grounding in radio electronic equipment
Lecture 12. Shielding
Lecture 13. Circuit design methods for EMC
Lecture 14. Designing signal and power lines with EMC in mind
Lecture 15. EMC modeling

Topic 4. Ensuring thermal conditions in the design of radio-electronic equipment

Lecture 16. Physical fundamentals of heat transfer in electronic equipment
Lectures 17-18. Thermal models of electronic equipment. Predicting temperature conditions
Lecture 19. Heat dissipation methods
Lecture 20. Thermal optimization of designs in CAD

Topic 5. Moisture protection

Lecture 21. Effect of humidity on the parameters and reliability of electronic equipment
Lecture 22. Methods of protection against moisture

Topic 6. Ensuring the mechanical stability of electronic equipment structures

Lecture 23. Mechanical loads: vibrations, shocks, linear accelerations, acoustic pressure
Lecture 24. Structural strength of elements and fasteners
Lecture 25. Methods of protection against mechanical loads. Dynamic modeling and testing of REA for stability

Topic 7. Technologies for the production of intelligent electronic equipment

Lecture 26. Methods of mechanical processing and manufacturing of housing parts. Technologies for assembling, connecting, and mounting elements
Lecture 27. Methods of automated and manual assembly of REA blocks
Lecture 28. Control, diagnostics, and testing of electronic equipment

Topic 8. Digital technologies and Industry 4.0 in the design and manufacture of electronic equipment

Lecture 29. The concept of Industry 4.0 and its impact on the design of electronic equipment. Digital manufacturing: digital twin and digital flow

Lecture 30. Digital manufacturing tools and platforms, augmented and virtual reality in the design and maintenance of electronic equipment

Practical classes

Practical classes are held for better assimilation and in-depth study of the lecture material. The topic of the practical class is communicated to students in advance, during the previous class or lecture.

No.	Name of the class topic and list of main questions (list of teaching materials, references to literature, and assignments for independent study)
1.	Hierarchy of intellectual radio-electronic equipment, main differences.
2.	Engineering design as a means of implementing a finished device.
3.	Calculation of key reliability indicators.
4.	Calculation of reliability indicators for gradual and sudden failures.
5.	Redundancy systems to increase the reliability and service life of of intellectual radio-electronic equipment.
6.	Basic means of protection against electromagnetic interference that may occur inside the device during its operation.
7.	Basic means of protection against external electromagnetic influences. Calculation their parameters.
8.	Causes of thermal field generation in the radio-electronic equipment unit and calculation of thermal load on its structural units.
9.	Calculation of the heat transfer coefficient as the main criterion for further modeling of thermal processes in CAD systems.
10.	Methods of heat removal and forced cooling, their calculation.
11.	Calculation of the thickness of protective coatings against moisture. Features of the choice of material and operating time.
12.	Methodology for calculating mechanical loads on electronic equipment during its operation, transportation, and storage.
13.	Methods of protection against mechanical loads and calculation of REA stability.
14.	Calculation of the main indicators of the manufacturability of electronic equipment design.
15	The concept of Industry 4.0 and its impact on the design logic of intelligent REA.

Laboratory work

The main objectives of the laboratory course are to develop the relevant skills and experience in students.

Laboratory work No. 1. Bench analysis of an intelligent REA unit. Determination of basic design

criteria.

Laboratory work No. 2. Limit testing of devices according to reliability criteria for gradual failures.

Laboratory work No. 3. Shielding of magnetostatic fields.

Laboratory work No. 4. Shielding of electrostatic (quasi-static) fields.

Laboratory work No. 5. Investigation of limitations caused by the requirements for stability and reliability of intelligent radio-electronic equipment.

Laboratory work No. 6. Calculation of tolerances for the output parameter of a semiconductor circuit under normal conditions and at elevated temperatures.

Laboratory work No. 7. Investigation of soldered connections

Laboratory work No. 8. Investigation of contact electric spot welding and the possibility of sealing by welding.

6. *Independent work of the student*

Types of independent work: studying lecture materials; completing tasks discussed in practical work; theoretical preparation for laboratory work; performing calculation and graphic work.
The assignment for the independent work is given during the third lecture and includes the calculation of the main parameters of the IntREA unit.
Higher education students can choose their own topics after prior consultation with their

teacher. Suggested topics for the final research project:

1. 1. Central controller "Smart Home" (CC SH)
2. Universal communication gateway "Hub-Pro"
3. Intelligent main module "Home Network"
4. Automation controller "Astra-Smart"
5. Intelligent photo processing, adaptive battery optimization.
6. Continuous health monitoring using AI algorithms, GPS navigation.
7. Active intelligent noise cancellation (ANC) that adapts to the environment.
8. Adaptive equalizer that adjusts the sound to the acoustics of the room/street.
9. Adaptive screen backlight depending on the time of day and lighting conditions.
10. AI-based adaptive water and detergent dosing.
11. System for monitoring food freshness and automatic temperature control.
12. Accurate room mapping and obstacle avoidance using LDS lidar.
13. Automatic detection of the number of people in the room and optimization of air flows.
14. Automatic response to pollution levels (dust, allergens) and intensive cleaning.

Policy and control

7. *Academic discipline policy (educational component)*

- At the beginning of the semester, a Telegram chat for the discipline is created for quick student-teacher interaction. All students in the group must be present in the chat;
- Attendance at laboratory work, practical classes, and lectures is mandatory.
- All laboratory assignments must be submitted to the instructor for review within the specified time frame. Late submissions will result in the loss of the right to redo the assignment to improve the grade.
- If the instructor has questions about the authorship of the work submitted by the student for review, the instructor has the right to conduct an additional defense of the work.

- Incentive points are awarded for student participation in lectures, practical and laboratory work.

Violation of deadlines for completing assignments and incentive points

The key measures in teaching the discipline are those that form the student's semester rating. Therefore, students must complete assignments in practical classes on time and write tests within the allotted time. There are no penalty points for the discipline. Students can receive bonus points for in-depth study of individual topics of the course, which can be presented in the form of scientific abstracts, scientific articles, essays, presentations, etc., as well as for active participation in discussions during practical and lecture classes. However, the total number of bonus points cannot exceed 10% of the rating scale.

Class attendance and behavior

No points are awarded for attendance at lectures, and no penalty points are awarded for missing classes. During classes, students are allowed to use interactive teaching aids, including accessing the Internet to search for educational or reference information, if this is required by the subject matter of the assignment. Student activity in class and their willingness to participate in discussions of academic issues may be rewarded with bonus points at the discretion of the instructor. Students must not interfere with the instructor's teaching and must not be distracted by activities unrelated to the learning process.

Missed tests

To check the degree of assimilation of theoretical material by students and their ability to use the knowledge gained in solving practical problems, a test is provided. If tests are missed for valid reasons (illness or significant life circumstances), the student is given the opportunity to take the test within the next week. Retaking a test is not permitted. In case of violation of deadlines and failure to complete the task for insignificant reasons, the student is not allowed to take the exam during the main session.

Deadline and retake policy

In case of academic debt or any force majeure circumstances, students should contact the instructor via available (provided by the instructor) communication channels to resolve issues and agree on a course of action for making up the work.

Academic Conduct and Ethics Policy

Students should be tolerant, respect the opinions of others, formulate objections in a polite manner, and constructively support feedback in class. The standards of ethical behavior for students and employees are defined in Section 2 of the Code of Honor of the National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute." For more details, see: https://kpi.ua/code. The policy on academic integrity is described in detail in the Code of Honor of Igor Sikorsky Kyiv Polytechnic Institute. This means that students take full responsibility for ensuring that all

- A prerequisite for admission to the exam is the absence of debts on the course, as well as a starting rating of at least 30 *points*.
- A student who scores less than 10 points on the exam (or scores *points* on one of the three questions) is considered to have received a final grade of "unsatisfactory" regardless of their semester rating.
- The student's calendar assessment is based on their current rating at the time of assessment. If this rating is at least 50% of the maximum possible at the time of assessment, the student is considered to have passed.

8. *Types of control and rating system for assessing learning outcomes*

Assessment is based on the use of a rating system, which requires students to work systematically

throughout the semester. A student's rating consists of points awarded for:

- completion of practical work (15 assignments), • completion of laboratory work (8 assignments), • completion of a modular control work (MCW),
- completion of computational and graphical work (CGW).

Criteria for awarding points.

Practical work is graded on a scale of 1 to 3 points per assignment. 3 points – flawless work, complete solution to the task with all comments and formatting. 2 points – there are shortcomings in the work, errors in calculations, incorrect explanations. 1 point – there are significant shortcomings in the work. All work must be completed by the end of the 15th week of the semester. Otherwise, no points will be awarded for them.

The completion of laboratory work is assessed with a maximum of 3 points for each piece of work. Of these, 1 point is for preparation for work, knowledge of theoretical material, 1 point is for taking measurements, constructing graphs of dependencies, performing calculations, and 1 point is for formatting the report and defending the work. The presence of grades for all defended laboratory work is a condition for admission to the exam.

The completion of the MCR is graded on a scale of up to 15 points. The MCR is conducted in the form of a test. A passing grade on the MCR is a prerequisite for admission to the exam.

The completion of the RGR is assessed at a maximum of 16 points. 15-16 points - the task is completed in full, 12-14 points - there are minor shortcomings in the work, 10-11 points - the work is completed with shortcomings, 5-9 points - the work is completed with significant shortcomings, but at least 60% of the work is completed. Less than 5 points – the work needs to be revised. A positive assessment of the RGR is a prerequisite for admission to the exam. The RGR must be completed by the end of the 15th week of the semester. Otherwise, no points will be awarded for it.

Table of correspondence between rating points and university scale grades

Number of points	*Grade*
100-95	Excellent
94	Very good
84	Good
74-65	Satisfactory
64-60	Sufficient
Less than 60	Unsatisfactory
Admission requirements not met	Not admitted

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

Certificates of completion of distance or online courses may be accepted as fulfillment of one of the types of work (practical or laboratory work) on the relevant topic. The relevance to the topic must be agreed with the lecturer.

Description of material, technical, and informational support for the discipline

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Work program of the academic discipline (syllabus):
Compiled by Novosad A. A.; Golovnya V. M.;
Approved by the PRE Department (Minutes No. 06/2025 dated 06/25/2025)
Approved by the methodological commission of the faculty/research institute (protocol No. 06/2025 dated 26.06.2025)