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| Federal State Budget Educational Institution of Higher Education  «MIREA – Russian Technological University» | | | | | | | | | | | | | | | | | | | | | |
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| **Institute of Physics and Technology** | | | | | | | | | | | | | | | | | | | | | |
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| Working program of the discipline (module) | | | | | | | | | | | | | | | | | | | | | |
| **Flexible management of engineering projects** | | | | | | | | | | | | | | | | | | | | | |
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|  | Department leading the training | | | | | |  |  | **Department of Informatics** | | | | | | | | | | | | |
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|  | Direction of training | | | | | | |  | **11.04.04 Electronics and nanoelectronics** | | | | | | | | | | | | |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  | Profile | | | | | | |  | **Engineering of modern materials for information technology, renewable energy and sensing** | | | | | | | | | | | | |
|  |  |  |  |  |  |  |  |  |
|  | Qualification | | | | |  |  |  | **Master** | | | | | | | | | | | | |
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|  | Form of education | | | | |  |  |  | **Full-time** | | | | | | | | | |  |  |  |
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|  | Total labor intensity | | | |  |  |  |  | **3 credits** | | | | | | | | | |  |  |  |
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| **Distribution of discipline hours and forms of intermediate certification by semesters** | | | | | | | | | | | | | | | | | | | | | |
| Semester | | Credits | Distribution of hours | | | | | | | | | | | | | | | Forms of intermediate attestation | | |  |
| Total | Lectures | | | | Laboratory work | | | Practical classes | Independent work of students | | Contact work during practice and (or) certification | | | Control of training |  |
| 2 | | 3 | 108 | 16 | | | | 0 | | | 16 | 58 | | 0,25 | | | 17,75 | Test | | |  |
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| The program was made by: |  |  |  |  |
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| *Ph.D. Economic Sciences, Professor, E. Mityakov\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_* | | | | |
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| Working program of the discipline | | |  |  |
| **Flexible management of engineering projects** | | | | |
|  |  |  |  |  |
| it is developed in accordance with FSES HE: | | |  |  |
| Federal State Educational Standard of Higher Education - Magistracy in the Direction of training 11.04.04 Electronics and nanoelectronics (order of the Ministry of Science and Higher Education of the Russian Federation from 22.09.2017. № 959) | | | | |
|  |  |  |  |  |
| it is based on the curriculum: | | |  |  |
| Direction of training: 11.04.04 Electronics and nanoelectronics  Profile: «Engineering of modern materials for information technology, renewable energy and sensing» | | | | |
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| The working program was approved at the meeting of the department | | | | |
| **Department of Informatics** | | | | |
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| Minutes of meeting from 22.03.2020 № 8  Head of the Department R. Shamin\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ | | | | |

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| **Approval of the WPD for execution in the next academic year** | | | | |
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| The working program was revised, discussed and approved for execution in the 2021-2022 academic year at a meeting of the department | | | | |
| **Department of Informatics** | | | | |
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|  | Minutes of meeting from \_\_ \_\_\_\_\_\_\_\_\_\_ 2021. № \_\_  Head of the Department \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ | | | |
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| **Approval of the WPD for execution in the next academic year** | | | | |
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| The working program was revised, discussed and approved for execution in the 2022-2023 academic year at a meeting of the department | | | | |
| **Department of Informatics** | | | | |
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|  | Minutes of meeting from \_\_ \_\_\_\_\_\_\_\_\_\_ 2022. № \_\_  Head of the Department \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ | | | |
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| **Approval of the WPD for execution in the next academic year** | | | | |
|  |  |  |  |  |
| The working program was revised, discussed and approved for execution in the 2023-2024 academic year at a meeting of the department | | | | |
| **Department of Informatics** | | | | |
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|  | Minutes of meeting from \_\_ \_\_\_\_\_\_\_\_\_\_ 2023. № \_\_  Head of the Department \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ | | | |
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| **Approval of the WPD for execution in the next academic year** | | | | |
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| The working program was revised, discussed and approved for execution in the 2024-2025 academic year at a meeting of the department | | | | |
| **Department of Informatics** | | | | |
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|  | Minutes of meeting from \_\_ \_\_\_\_\_\_\_\_\_\_ 2024. № \_\_  Head of the Department \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ | | | |
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| **1. OBJECTIVES OF MASTERING THE DISCIPLINE (MODULE)** | | | | | |
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| The discipline «Flexible management of engineering projects» aims to contribute to the formation of students’ competencies, provided by this work program in accordance with the requirements of FSES HE in the direction of training 11.04.04 Electronics and nanoelectronics, taking into account the specifics of the profile – «Engineering of modern materials for information technology, renewable energy and sensing». | | | | | |
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| **2. PLACE OF DISCIPLINE (MODULE) IN THE STRUCTURE OF THE EDUCATIONAL PROGRAM** | | | | | |
|  | Direction of training: |  | 11.04.04 Electronics and nanoelectronics | | |
|  |
|  | Profile: |  | Engineering of modern materials for information technology, renewable energy and sensing | | |
|  |  |  |
|  | Block: |  | Disciplines (modules) | | |
|  |  |  |
|  | Part: |  | Mandatory part | | |
|  |  |  |
|  | Total labor intensity: |  | 3 credits (108 academic hours). | | |
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| **3. THE STUDENT’S COMPETENCIES FORMED AS A RESULT OF MASTERING THE DISCIPLINE (MODULE)** | | | | | |
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| As a result of mastering the practice, the student must master the following competencies: | | | | | |
| **UC-1** - Capable to carry out a critical analysis of problem situations on the basis of a systematic approach, develop a strategy of action | | | | | |
| **UC-2** - Capable to manage a project at all stages of its life cycle | | | | | |
| **UC-3** - Capable to organize and lead the work of the team, developing team strategy to achieve this goal | | | | | |
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| **PLANNED RESULTS OF TRAINING IN THE DISCIPLINE (MODULE), CHARACTERIZING THE FORMATION OF COMPETENCIES** | | | | | |
|  |  |  |  |  |  |
| **UC-1 : Capable to carry out a critical analysis of problem situations on the basis of a systematic approach, develop a strategy of action** | | | | | |
|  |  |  |  |  |  |
| **UC-1.1: Analyzes the problem situation as a system, identifying its components and the relationships between them** | | | | | |
| **To know:** | | | | | |
| - Modern project management methods | | | | | |
| **Be able to:** | | | | | |
| - On the basis of the problem posed, form a project task and a way to solve it through the implementation of flexible project management | | | | | |
| **Possess:** | | | | | |
| - Project management skills using a flexible methodology | | | | | |
|  |  |  |  |  |  |
| **UC-1.2: Identifies gaps in information needed to solve the problematic situation; critically assesses the reliability of information sources** | | | | | |
| **To know:** | | | | | |
| - Methods of developing a flexible management concept and a project implementation plan, taking into account possible implementation risks and opportunities to eliminate them | | | | | |
| **Be able to:** | | | | | |
| - Develop the concept of an engineering project within the framework of the identified problem and a project implementation plan, taking into account possible implementation risks and opportunities to eliminate them using a flexible methodology | | | | | |

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| **Possess:** | | |
| - Skills in developing the concept of an engineering project using a flexible methodology | | |
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| **UC-2 : Capable to manage a project at all stages of its life cycle** | | |
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| **UC-2.1: Forms a project task based on the problem posed, the way to solve it through the implementation of project management** | | |
| **To know:** | | |
| - Modern project management methods | | |
| **Be able to:** | | |
| - On the basis of the problem posed, form a project task and a way to solve it through the implementation of flexible project management | | |
| **Possess:** | | |
| - Project management skills using a flexible methodology | | |
|  |  |  |
| **UC-2.2: Develops a project concept within the framework of the designated problem and a project implementation plan, taking into account possible implementation risks and opportunities to eliminate them** | | |
| **To know:** | | |
| - Methods of developing a flexible management concept and a project implementation plan, taking into account possible implementation risks and opportunities to eliminate them | | |
| **Be able to:** | | |
| - Develop the concept of an engineering project within the framework of the identified problem and a project implementation plan, taking into account possible implementation risks and opportunities to eliminate them using a flexible methodology | | |
| **Possess:** | | |
| - Skills in developing the concept of an engineering project using a flexible methodology | | |
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| **UC-3 : Capable to organize and lead the work of the team, developing team strategy to achieve this goal** | | |
|  |  |  |
| **UC-3.1: Develops strategy of teamwork and on its basis organizes the selection of team members to achieve the goal** | | |
| **To know:** | | |
| - Modern project management methods | | |
| **Be able to:** | | |
| - On the basis of the problem posed, form a project task and a way to solve it through the implementation of flexible project management | | |
| **Possess:** | | |
| - Project management skills using a flexible methodology | | |
|  |  |  |
| **UC-3.2: Organizes and modifies the work of the team, including on the basis of collegial decisions** | | |
| **To know:** | | |
| - Methods of developing a flexible management concept and a project implementation plan, taking into account possible implementation risks and opportunities to eliminate them | | |
| **Be able to:** | | |
| - Develop the concept of an engineering project within the framework of the identified problem and a project implementation plan, taking into account possible implementation risks and opportunities to eliminate them using a flexible methodology | | |
| **Possess:** | | |

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| - Skills in developing the concept of an engineering project using a flexible methodology | | | | | | |
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| **AS A RESULT OF STUDYING THE DISCIPLINE (MODULE), THE STUDENT MUST** | | | | | | |
|  |  |  |  |  |  |  |
| **To know:** | | | | | | |
| - Methods of developing a flexible management concept and a project implementation plan, taking into account possible implementation risks and opportunities to eliminate them | | | | | | |
| - Modern project management methods | | | | | | |
| - Modern project management methods | | | | | | |
| - Methods of developing a flexible management concept and a project implementation plan, taking into account possible implementation risks and opportunities to eliminate them | | | | | | |
| - Methods of developing a flexible management concept and a project implementation plan, taking into account possible implementation risks and opportunities to eliminate them | | | | | | |
| - Modern project management methods | | | | | | |
| **Be able to:** | | | | | | |
| - On the basis of the problem posed, form a project task and a way to solve it through the implementation of flexible project management | | | | | | |
| - Develop the concept of an engineering project within the framework of the identified problem and a project implementation plan, taking into account possible implementation risks and opportunities to eliminate them using a flexible methodology | | | | | | |
| - On the basis of the problem posed, form a project task and a way to solve it through the implementation of flexible project management | | | | | | |
| - Develop the concept of an engineering project within the framework of the identified problem and a project implementation plan, taking into account possible implementation risks and opportunities to eliminate them using a flexible methodology | | | | | | |
| - Develop the concept of an engineering project within the framework of the identified problem and a project implementation plan, taking into account possible implementation risks and opportunities to eliminate them using a flexible methodology | | | | | | |
| - On the basis of the problem posed, form a project task and a way to solve it through the implementation of flexible project management | | | | | | |
| **Possess:** | | | | | | |
| - Skills in developing the concept of an engineering project using a flexible methodology | | | | | | |
| - Project management skills using a flexible methodology | | | | | | |
| - Skills in developing the concept of an engineering project using a flexible methodology | | | | | | |
| - Project management skills using a flexible methodology | | | | | | |
| - Skills in developing the concept of an engineering project using a flexible methodology | | | | | | |
| - Project management skills using a flexible methodology | | | | | | |
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| **4. STRUCTURE AND CONTENT OF THE DISCIPLINE (MODULE)** | | | | | | |
| During the training sessions, the organization ensures the development of students’ teamwork skills, interpersonal communication, decision-making and leadership qualities. | | | | | | |
| **Code** | **Name of sections and topics /type of classes/** | | **Semester** | **Academic Hours** | **Competencies** | |
| **1. Flexible management of engineering projects** | | | | | | |

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| **1.1** | **The main provisions of project management (Lec).** Introduction to Project Management. The concept of the project. Basic definitions of projects. The main features of the project. Types of projects. Project participants. The main Competencies and areas of responsibility of the project participants. Project management standards. | 2 | 2 | UC-1.1, UC- 1.2, UC-2.1, UC-2.2, UC- 3.1, UC-3.2 |
| **1.2** | **Performing practical tasks (Pr).** Project initiation and planning phases. The composition of the project management plan. Selection/coordination of project topics | 2 | 2 | UC-1.1, UC- 1.2, UC-2.1, UC-2.2, UC- 3.1, UC-3.2 |
| **1.3** | **Preparation for classroom classes (IWS).** Study of lecture materials. Preparation for a practical lesson. | 2 | 7 | UC-1.1, UC- 1.2, UC-2.1, UC-2.2, UC- 3.1, UC-3.2 |
| **1.4** | **Modern project management methods** **(Lec).** A brief history of project management. Popular project management systems. Classical project management. Agile. Scrum. Lean. Kanban. Six Sigma. PRINCE2. | 2 | 2 | UC-1.1, UC- 1.2, UC-2.1, UC-2.2, UC- 3.1, UC-3.2 |
| **1.5** | **Performing practical tasks (Pr).** Choosing a project management method, defining the goals and objectives of the project. | 2 | 2 | UC-1.1, UC- 1.2, UC-2.1, UC-2.2, UC- 3.1, UC-3.2 |
| **1.6** | **Preparation for classroom classes (IWS).** Study of lecture materials. Preparation for a practical lesson. | 2 | 7 | UC-1.1, UC- 1.2, UC-2.1, UC-2.2, UC- 3.1, UC-3.2 |
| **1.7** | **Project content management (Lec).** The concept of the project and its evaluation criteria. The life cycle of the project. Creating a hierarchical structure of the project. | 2 | 2 | UC-1.1, UC- 1.2, UC-2.1, UC-2.2, UC- 3.1, UC-3.2 |
| **1.8** | **Performing practical tasks (Pr).** Project life cycle analysis. Creating a hierarchical structure of the project. | 2 | 2 | UC-1.1, UC- 1.2, UC-2.1, UC-2.2, UC- 3.1, UC-3.2 |
| **1.9** | **Preparation for classroom classes (IWS).** Study of lecture materials. Preparation for a practical lesson. | 2 | 7 | UC-1.1, UC- 1.2, UC-2.1, UC-2.2, UC- 3.1, UC-3.2 |
| **1.10** | **Project timeline management (Lec).** Managing project deadlines. Determination of the sequence and duration of operations. Development and management of the project schedule. | 2 | 2 | UC-1.1, UC- 1.2, UC-2.1, UC-2.2, UC- 3.1, UC-3.2 |
| **1.11** | **Performing practical tasks (Pr).** Determination of the sequence and duration of operations. Development and management of the project schedule. | 2 | 2 | UC-1.1, UC- 1.2, UC-2.1, UC-2.2, UC- 3.1, UC-3.2 |
| **1.12** | **Preparation for classroom classes (IWS).** Study of lecture materials. Preparation for a practical lesson. | 2 | 7 | UC-1.1, UC- 1.2, UC-2.1, UC-2.2, UC- 3.1, UC-3.2 |

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| **1.13** | **Prerequisites for the emergence of flexible management (Lec).** The state of the flexible management area. Comparison of cascading/iterative/Agile processes | 2 | 2 | UC-1.1, UC- 1.2, UC-2.1, UC-2.2, UC- 3.1, UC-3.2 |
| **1.14** | **Performing practical tasks (Pr).** Analysis of the applicability of flexible project management. Drawing up a flexible project management plan. | 2 | 2 | UC-1.1, UC- 1.2, UC-2.1, UC-2.2, UC- 3.1, UC-3.2 |
| **1.15** | **Preparation for classroom classes (IWS).** Study of lecture materials. Preparation for a practical lesson. | 2 | 7 | UC-1.1, UC- 1.2, UC-2.1, UC-2.2, UC- 3.1, UC-3.2 |
| **1.16** | **Flexible Management Philosophy (Lec).** Types of Agile methodologies and their prevalence. Scrum is a flexible management process. Adaptation of personnel to Scrum. Resistance control. A management object in Scrum. | 2 | 2 | UC-1.1, UC- 1.2, UC-2.1, UC-2.2, UC- 3.1, UC-3.2 |
| **1.17** | **Performing practical tasks (Pr).** Drawing up a flexible project management plan. Development of measures to adapt personnel to flexible project management. | 2 | 2 | UC-1.1, UC- 1.2, UC-2.1, UC-2.2, UC- 3.1, UC-3.2 |
| **1.18** | **Preparation for classroom classes (IWS).** Study of lecture materials. Preparation for a practical lesson. | 2 | 7 | UC-1.1, UC- 1.2, UC-2.1, UC-2.2, UC- 3.1, UC-3.2 |
| **1.19** | **Team building in flexible project management (Lec).** Stages of team building. Distribution of roles in flexible management. | 2 | 2 | UC-1.1, UC- 1.2, UC-2.1, UC-2.2, UC- 3.1, UC-3.2 |
| **1.20** | **Performing practical tasks (Pr).** Distribution of roles in flexible management | 2 | 2 | UC-1.1, UC- 1.2, UC-2.1, UC-2.2, UC- 3.1, UC-3.2 |
| **1.21** | **Preparation for classroom classes (IWS).** Study of lecture materials. Preparation for a practical lesson. | 2 | 8 | UC-1.1, UC- 1.2, UC-2.1, UC-2.2, UC- 3.1, UC-3.2 |
| **1.22** | **Flexible project planning** **(Lec).** The principle of rapid planning. Step-by-step clarification of plans. Planning techniques. | 2 | 2 | UC-1.1, UC- 1.2, UC-2.1, UC-2.2, UC- 3.1, UC-3.2 |
| **1.23** | **Performing practical tasks (Pr).** Clarification of flexible project plans. Analysis of various planning techniques. | 2 | 2 | UC-1.1, UC- 1.2, UC-2.1, UC-2.2, UC- 3.1, UC-3.2 |
| **1.24** | **Preparation for classroom classes (IWS).** Study of lecture materials. Preparation for a practical lesson. | 2 | 8 | UC-1.1, UC- 1.2, UC-2.1, UC-2.2, UC- 3.1, UC-3.2 |

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| **2. Intermediate certification (Test)** | | | | | | |
| **2.1** | **Preparation for the intermediate certification (Test).** | | 2 | 17,75 | UC-1.1, UC- 1.2, UC-2.1, UC-2.2, UC- 3.1, UC-3.2 | |
| **2.2** | **Contact work with the teacher during the intermediate certification (CWC).** | | 2 | 0,25 | UC-1.1, UC- 1.2, UC-2.1, UC-2.2, UC- 3.1, UC-3.2 | |
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| **5. EVALUATION MATERIALS** | | | | | | |
|  |  |  |  |  |  |  |
| **5.1. List of competencies** | | | | | | |
|  |  |  |  |  |  |  |
| List of competencies, the development of which the study of the discipline is aimed at «Flexible management of engineering projects», with an indication of the results of their formation in the process of mastering the educational program, presented in paragraph 3 of this work program | | | | | | |
| **5.2. Typical control questions and tasks** | | | | | | |
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| Questions to prepare for the Test/exam  1. The main provisions of project management. The concept of the project.  2. Basic definitions of projects. The main features of the project.  3. Types of projects. Project participants.  4. The main Competencies and areas of responsibility of the project participants.  5. Project management standards.  6. A brief history of project management. Popular project management systems.  7. Classical project management.  8. Agile. Scrum. Lean.  9. Kanban. Six Sigma. PRINCE2.  10. The concept of the project and its evaluation criteria.  11. Project life cycle. Creating a hierarchical structure of the project.  12. Project timeline management. Determination of the sequence and duration of operations.  13. Development and management of the project schedule.  14. The state of the flexible management area.  15. Comparison of cascading/iterative/Agile processes  16. The team. Stages of team building.  17. Distribution of roles in flexible management.  18. The principle of rapid planning.  19. Step-by-step clarification of plans. Planning techniques.  20. Stages and activities of flexible design. Sprint. Daily meetings.  21. Grooming of business tasks. Grooming of technical tasks. Retrospective analysis.  22. Attributes of flexible management. Story mapping.  23. User stories. Determining user priorities.  24. Task board.  25. Product backlog. Sprint backlog.  26. Product increment. The principle of prototyping.  27. Project cost management. Approaches to determining the risk factor.  28. Classification of risks. Risk management methods.  29. Stages of preparation and main sections of the business plan.  30. The main sections of the business plan.  31. Development of a financial and investment strategy. The algorithm of financial planning.  32. Calculation of break-even. | | | | | | |

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| 33. Analysis of the effectiveness of the project.  34. Analysis of the financial feasibility of the project.  35. Project sustainability analysis.  36. Analysis of the elasticity of project indicators.  37. Qualitative risk analysis.  38. Quantitative risk analysis.  39. Evaluation of the project potential.  40. Sources of financing of technological projects. | | | | | |
| **5.3. Fund of evaluation Materials** | | | | | |
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| A complete list of evaluation materials is provided in the Appendix 1. | | | | | |
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| **6. MATERIAL, TECHNICAL, EDUCATIONAL AND METHODOLOGICAL SUPPORT OF THE DISCIPLINE (MODULE)** | | | | | |
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| **6.1. MATERIAL AND TECHNICAL SUPPORT OF THE DISCIPLINE (МОДУЛЯ)** | | | | | |
| **Name of premises** | | | | **List of main equipment** | |
| Classroom for lectures and seminars, group and individual consultations, ongoing monitoring and intermediate certification | | | | Multimedia equipment, specialized furniture, sets of demonstration equipment and educational and visual aids that provide thematic illustrations. | |
| Computer classroom | | | | Computer equipment with the ability to connect to the Internet, multimedia equipment, specialized furniture. | |
| A room for independent work of students | | | | Computer equipment with the ability to connect to the Internet and provide access to the electronic information and educational environment of the organization. | |
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| **6.2. LIST OF SOFTWARE** | | | | | |
| 1. |  | Microsoft Windows. Contract No. 32009183466 from 02.07.2021. | | | |
| 2. |  | Microsoft Office. Contract No. 32009183466 from 02.07.2021. | | | |
| 3. |  | Python. Free software (License PSFL) | | | |
| 4. |  | Microsoft Visual Studio Community. Free software (License Microsoft EULA) | | | |
| 5. |  | Apache Hadoop. Free software (License Apache License 2.0) | | | |
| 6. |  | Apache Hive. Free software (License Apache License 2.0) | | | |
| 7. |  | Apache Spark. Free software (License Apache License 2.0) | | | |
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| **6.3. RECOMMENDED LITERATURE** | | | | | |
|  |  |  |  |  |  |
| **6.3.1. Basic literature** | | | | | |
| 1. |  | Heldman K. Professional'noe upravlenie proektom:Per. s angl.. - M.: Laboratoriya znanij, 2016. - 760 p. | | | |
| 2. |  | Budovich L. S., Starceva YU. V. Biznes-planirovanie v predprinimatel'skoj deyatel'nosti [Electronic resource]: uchebno-metodicheskoe posobie. - M.: RTU MIREA, 2021.- – Access mode: https://library.mirea.ru/secret/25082021/2791.iso | | | |
| 3. |  | Sazerlend Dzh. Scrum. Revolyucionnyj metod upravleniya proektami:per. s angl.. - M.: OOO "Mann, Ivanov i Ferber", 2016. - 280 p. | | | |
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| **6.3.2. Additional literature** | | | | | |

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| 1. |  | CHusavitina G. N., Makashova V. N. Upravlenie proektami po razrabotke i vnedreniyu informacionnyh sistem [Electronic resource]:ucheb. posobie. - Moscow: FLINTA,2019. - 224 с. – Access mode: https://e.lanbook.com/book/125428 | | |
| 2. |  | Alekseeva N. V. Upravlenie proektami. CH.1 [Electronic resource]:uchebno-metodicheskoe posobie. - Moscow: RTU MIREA,2021. - – Access mode: https://library.mirea.ru/secret/07042021/2614.iso | | |
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| **6.4. RECOMMENDED LIST OF MODERN PROFESSIONAL DATABASES AND INFORMATION REFERENCE SYSTEMS** | | | | |
| 1. |  | Russian Software Developer Network — community of Russian-speaking software developers https://www.rsdn.org | | |
| 2. |  | IEEE International Roadmap for Devices and Systems  https://www.irds.ieee.org | | |
| 3. |  | Information and reference portal of scientific publications of domestic and foreign authors «Google Academy»  https://www.scholar.google.ru | | |
| 4. |  | Russian Technological Journal  https://www.rtj.mirea.ru | | |
| 5. |  | Electronic fund of legal and regulatory technical documentation Tekhnoexpert http://www.docs.cntd.ru | | |
| 6. |  | Consultant Plus http:// www.consultant.ru | | |
| 7. |  | Scientific Electronic Library http://www.elibrary.ru | | |
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| **6.5. METHODICAL INSTRUCTIONS FOR STUDENTS STUDYING THE DISCIPLINE (MODULE)** | | | | |
| The student’s independent work is aimed at preparing for academic classes and at developing knowledge, skills and abilities provided for in the discipline program.  In accordance with the curriculum, the discipline may include Lectures, practical classes and Laboratory work, as well as the execution and defense of a course project (work). Successful study of the discipline requires attending all types of classes, completing teacher assignments and familiarization with basic and additional literature. Depending on the activities provided for in the curriculum and section 4 of this program, the student chooses methodological guidelines for independent work from the ones listed below.  When preparing for lecture classes, students need to:  before the next lecture, it is necessary to review the summary of the material of the previous Lectures. If you have difficulties in perceiving the material, you should refer to the main literary sources. If it was not possible to understand the material again, then contact the lecturer (according to the schedule of his consultations) or the teacher in practical classes.  Practical classes complete the study of the most important topics of the discipline. They serve to consolidate the studied material, develop the skills and abilities of preparing reports, messages, gaining experience in oral public speeches, conducting discussions, argumentation and defending the propositions put forward, as well as to monitor the degree of readiness of students in the discipline being studied by the teacher.  When preparing for a practical lesson, students have the opportunity to use the advice of a teacher.  When preparing for practical classes, students need to:  bring with you the literature recommended by the teacher for a specific lesson;  before the next practical lesson on the recommended literary sources, work out the theoretical material corresponding to the topic of the lesson;  at the beginning of classes, ask the teacher questions about the material that caused difficulties in understanding and mastering it when solving tasks set for independent solution; | | | | |

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| during the seminar, give specific, clear answers to the substance of the questions;  at the training session, bring each task to the final solution, demonstrate an understanding of the calculations (analyses, situations), in case of difficulties, contact the teacher.  Students who have missed classes (regardless of the reasons), who do not have a written solution to problems or are not prepared for this practical lesson, are recommended to come to the teacher’s consultation no later than 2 weeks and report on the topic studied in the lesson.  The methodological guidelines necessary for studying and passing the discipline are given as part of the educational program. | | |
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| **6.6. METHODOLOGICAL RECOMMENDATIONS FOR THE TRAINING OF PERSONS WITH LIMITED HEALTH OPPORTUNITIES AND THE DISABLED** | | |
| The development of the discipline by students with disabilities can be organized both jointly with other students and in separate groups. Special conditions are assumed for students with disabilities to receive education.  The teaching staff gets acquainted with the psychological and physiological characteristics of students with disabilities and persons with disabilities, individual rehabilitation programs for the disabled (if available). If necessary, additional teaching support is provided by tutors, psychologists, social workers, trained assistants.  In accordance with the methodological recommendations of the Ministry of Education and Science of the Russian Federation (approved April 8, 2014 N AK-44/05vn), the course is supposed to use socially active and reflective teaching methods, technologies of socio-cultural rehabilitation in order to assist in establishing full-fledged interpersonal relationships with other students, creating a comfortable psychological climate in the student group. Selection and development of educational materials are made taking into account the provision of material in various forms: auditory, visual, using special technical means and information systems.  Mediamaterials should also be used and adapted taking into account the individual characteristics of the training of persons with disabilities.  The development of the discipline by persons with disabilities is carried out using general and special purpose teaching tools (personal and collective use). Material and technical support provides for the adaptation of classrooms to the needs of persons with disabilities.  The form of certification for students with disabilities is established taking into account individual psychophysical characteristics. For students with HIA, an accessible form of assignment of assessment tools is provided, namely:  - in printed or electronic form (for persons with disorders of the musculoskeletal system);  - in printed or electronic form with enlarged font and contrast (for persons with hearing, speech, vision impairments);  - reading the task aloud by the assistant (for visually impaired persons).  Students with disabilities have increased time to prepare answers to control questions. For such students, an accessible form of providing answers to tasks is provided, namely:  - written on paper or a set of answers on a computer (for persons with hearing and speech impairments);  - choosing an answer from possible options using the services of an assistant (for people with musculoskeletal disorders);  - oral interview (for persons with visual impairments, musculoskeletal system).  If necessary, for students with disabilities, the procedure for evaluating learning outcomes can be carried out in several stages. | | |

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| MINISTRY OF SCIENCE AND HIGHER EDUCATION OF THE RUSSIAN FEDERATION | | | | | | | | | | | | | | | | | | | | | |
| Federal State Budget Educational Institution of Higher Education  «MIREA – Russian Technological University» | | | | | | | | | | | | | | | | | | | | | |
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| Working program of the discipline (module) | | | | | | | | | | | | | | | | | | | | | |
| **Innovative materials and system integration for information technologies** | | | | | | | | | | | | | | | | | | | | | |
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|  | Department leading the training | | | | | |  |  | **Department of Nanoelectronics** | | | | | | | | | | | | |
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|  | Direction of training | | | | | | |  | **11.04.04 Electronics and nanoelectronics** | | | | | | | | | | | | |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  | Profile | | | | | | |  | **Engineering of modern materials for information technology, renewable energy and sensing** | | | | | | | | | | | | |
|  |  |  |  |  |  |  |  |  |
|  | Qualification | | | | |  |  |  | **Master** | | | | | | | | | | | | |
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|  | Form of education | | | | |  |  |  | **Full-time** | | | | | | | | | |  |  |  |
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|  | Total labor intensity | | | |  |  |  |  | **8 credits** | | | | | | | | | |  |  |  |
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| **Distribution of discipline hours and forms of intermediate certification by semesters** | | | | | | | | | | | | | | | | | | | | | |
| Semester | | Credits | Distribution of hours | | | | | | | | | | | | | | | Forms of intermediate attestation | | |  |
| Total | Lectures | | | | Laboratory work | | | Practical classes | Independent work of students | | Contact work during practice and (or) certification | | | Control of training |  |
| 2 | | 4 | 144 | 16 | | | | 16 | | | 32 | 62 | | 0,25 | | | 17,75 | Test | | |  |
| including for practicing practical skills | | | | 0 | | | | 8 | | | 0 | 0 | | 0 | | | 0 |  | | |  |
| 3 | | 4 | 144 | 16 | | | | 0 | | | 32 | 60 | | 2,35 | | | 33,65 | Exam | | |  |
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| The program was made by: |  |  |  |  |
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| *Ph.D. Physics and Mathematics, Associate Professor, I. Gladyshev \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_* | | | | |
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| Working program of the discipline | | |  |  |
| **Innovative materials and system integration for information technologies** | | | | |
|  |  |  |  |  |
| it is developed in accordance with FSES HE: | | |  |  |
| Federal State Educational Standard of Higher Education - Magistracy in the Direction of training 11.04.04 Electronics and nanoelectronics (order of the Ministry of Science and Higher Education of the Russian Federation from 22.09.2017. № 959) | | | | |
|  |  |  |  |  |
| it is based on the curriculum: | | |  |  |
| Direction of training: 11.04.04 Electronics and nanoelectronics  Profile: «Engineering of modern materials for information technology, renewable energy and sensing» | | | | |
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| The working program was approved at the meeting of the department | | | | |
| **Department of Nanoelectronics** | | | | |
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| Minutes of meeting from 02.03.2021 № 3  Head of the Department A. Sigov \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ | | | | |

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| **Approval of the WPD for execution in the next academic year** | | | | |
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| The working program was revised, discussed and approved for execution in the 2022-2023 academic year at a meeting of the department | | | | |
| **Department of Nanoelectronics** | | | | |
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|  | Minutes of meeting from \_\_ \_\_\_\_\_\_\_\_\_\_ 2022. № \_\_  Head of the Department \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ | | | |
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| **Approval of the WPD for execution in the next academic year** | | | | |
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| The working program was revised, discussed and approved for execution in the 2023-2024 academic year at a meeting of the department | | | | |
| **Department of Nanoelectronics** | | | | |
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|  | Minutes of meeting from \_\_ \_\_\_\_\_\_\_\_\_\_ 2023. № \_\_  Head of the Department \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ | | | |
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| **Approval of the WPD for execution in the next academic year** | | | | |
|  |  |  |  |  |
| The working program was revised, discussed and approved for execution in the 2024-2025 academic year at a meeting of the department | | | | |
| **Department of Nanoelectronics** | | | | |
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|  | Minutes of meeting from \_\_ \_\_\_\_\_\_\_\_\_\_ 2024. № \_\_  Head of the Department \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ | | | |
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| **Approval of the WPD for execution in the next academic year** | | | | |
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| The working program was revised, discussed and approved for execution in the 2025-2026 academic year at a meeting of the department | | | | |
| **Department of Nanoelectronics** | | | | |
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|  | Minutes of meeting from \_\_ \_\_\_\_\_\_\_\_\_\_ 2025. № \_\_  Head of the Department \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ | | | |
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| **1. OBJECTIVES OF MASTERING THE DISCIPLINE (MODULE)** | | | | | |
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| The discipline «Innovative materials and system integration for information technologies» aims to contribute to the formation of students’ competencies, provided by this work program in accordance with the requirements of FSES HE in the direction of training 11.04.04 Electronics and nanoelectronics, taking into account the specifics of the profile – «Engineering of modern materials for information technology, renewable energy and sensing». | | | | | |
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| **2. PLACE OF DISCIPLINE (MODULE) IN THE STRUCTURE OF THE EDUCATIONAL PROGRAM** | | | | | |
|  | Direction of training: |  | 11.04.04 Electronics and nanoelectronics | | |
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|  | Profile: |  | Engineering of modern materials for information technology, renewable energy and sensing | | |
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|  | Block: |  | Disciplines (modules) | | |
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|  | Part: |  | Part of the curriculum formed by the participants of educational | | |
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|  | Total labor intensity: |  | 8 credits (288 academic hours). | | |
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| **3. THE STUDENT’S COMPETENCIES FORMED AS A RESULT OF MASTERING THE DISCIPLINE (MODULE)** | | | | | |
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| As a result of mastering the practice, the student must master the following competencies: | | | | | |
| **PC-3** - Capable of determining possible physical implementation options, physical and mathematical models of micro- and nanosystems and using software tools for their design and modeling | | | | | |
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| **PLANNED RESULTS OF TRAINING IN THE DISCIPLINE (MODULE), CHARACTERIZING THE FORMATION OF COMPETENCIES** | | | | | |
|  |  |  |  |  |  |
| **PC-3 : Capable of determining possible physical implementation options, physical and mathematical models of micro- and nanosystems and using software tools for their design and modeling** | | | | | |
|  |  |  |  |  |  |
| **PC-3.1: Defines possible variants of physical and mathematical models in the field of nanoelectronics** | | | | | |
| **To know:** | | | | | |
| - basic principles of drawing up computational models of physical systems | | | | | |
| **Be able to:** | | | | | |
| - apply knowledge of physical laws for qualitative analysis of computational models | | | | | |
| **Possess:** | | | | | |
| - skills of drawing up algorithms for computational models of physical systems | | | | | |
|  |  |  |  |  |  |
| **PC-3.2: Uses software tools for designing and modeling electronics elements** | | | | | |
| **To know:** | | | | | |
| - the most common software tools for designing and modeling electronics elements | | | | | |
| **Be able to:** | | | | | |
| - determine the software tools that are most suitable for solving the task | | | | | |
| **Possess:** | | | | | |

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| - skills of using any software tool for designing and modeling electronics elements | | | | | | |
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| **AS A RESULT OF STUDYING THE DISCIPLINE (MODULE), THE STUDENT MUST** | | | | | | |
|  |  |  |  |  |  |  |
| **To know:** | | | | | | |
| - the most common software tools for designing and modeling electronics elements | | | | | | |
| - basic principles of drawing up computational models of physical systems | | | | | | |
| **Be able to:** | | | | | | |
| - determine the software tools that are most suitable for solving the task | | | | | | |
| - apply knowledge of physical laws for qualitative analysis of computational models | | | | | | |
| **Possess:** | | | | | | |
| - skills of using any software tool for designing and modeling electronics elements | | | | | | |
| - skills of drawing up algorithms for computational models of physical systems | | | | | | |
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| **4. STRUCTURE AND CONTENT OF THE DISCIPLINE (MODULE)** | | | | | | |
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| During the training sessions, the organization ensures the development of students’ teamwork skills, interpersonal communication, decision-making and leadership qualities. | | | | | | |
| **Code** | **Name of sections and topics /type of classes/** | | **Semester** | **Academic Hours** | **Competencies** | |
| **1. Innovative materials** | | | | | | |
| **1.1** | **Lecture** **1.** **Miniaturization problems.** **(Lec).** Leakage currents. Problems of heat removal. The problem of heat dissipation and the reversibility of computation. Problems with the miniaturization of interconnects. Scaling restrictions. Tunnel effect. | | 2 | 2 | PC-3.1 | |
| **1.2** | **Lecture 2.** **Nanoclusters and nanomaterials.** **(Lec).** Nanoclusters and their classification. Methods for obtaining various nanoclusters and nanostructures. Nanomaterials. | | 2 | 2 | PC-3.1 | |
| **1.3** | **Lecture** **3.** **Carbon nanoclusters, nanostructures and nanomaterials (Lec).** Carbon nanoclusters. Fullerenes. Fullerites. Carbon nanotubes. Graphene. | | 2 | 2 | PC-3.1 | |
| **1.4** | **Lecture** **4.** **Bulk nanostructured materials (Lec).** Solid-state nanoclusters and nanostructures. Nanostructures and their properties. Thin films. Metal nanoclusters in optical glasses. Porous silicon. Volumetric nanostructured materials for photonics. | | 2 | 2 | PC-3.1 | |
| **1.5** | **Lecture** **5.** **Electrical and magnetic properties of nanosystems and nanomaterials (Lec).** Electrical properties of nanostructures. Magnetic properties of nanostructures. Ferromagnetic liquids | | 2 | 2 | PC-3.1 | |

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| **1.6** | **Lecture** **6.** **Self-assembly and catalysis. Surface effects (Lec).** The process of self-assembly. Monolayers. Surface effects. Electronic properties of the surface of metals and metal oxides. Magnetic properties of the surface of metals and metal oxides. Adsorption and catalysis. Thermodynamic approach to the surface. | 2 | 2 | PC-3.1 |
| **1.7** | **Lecture** **7.** **Biological nanostructures (Lec).** Macromolecular and supramolecular nanostructures. Biopolymers. Squirrels. DNA is a duplicated nanowire. Micelles and vesicles. Emulsion. Features of the structure and scope of nanomaterials in medicine. | 2 | 2 | PC-3.1 |
| **1.8** | **Lecture** **8.** **Applications of nanomaterials and nanotechnologies.** **(Lec).** Classification of low-dimensional systems. Quantum wells, wires and dots. Optical properties of quantum dots (0D systems). Optical properties of nanoclusters, nanosystems and nanomaterials. Metal nanoclusters. Optical properties of semiconductor nanoclusters. Quantum dot lasers. Semiconductor nanostructures and nanodevices. | 2 | 2 | PC-3.1 |
| **1.9** | **Oral interview (Pr).** Control questions | 2 | 2 | PC-3.1 |
| **1.10** | **Oral interview (Pr).** Control questions | 2 | 2 | PC-3.1 |
| **1.11** | **Oral interview (Pr).** Control questions | 2 | 2 | PC-3.1 |
| **1.12** | **Oral interview (Pr).** Control questions | 2 | 2 | PC-3.1 |
| **1.13** | **Oral interview (Pr).** Control questions | 2 | 2 | PC-3.1 |
| **1.14** | **Oral interview (Pr).** Control questions | 2 | 2 | PC-3.1 |
| **1.15** | **Oral interview (Pr).** Control questions | 2 | 2 | PC-3.1 |
| **1.16** | **Oral interview (Pr).** Control questions | 2 | 2 | PC-3.1 |
| **1.17** | **Defense of essays** **(Pr).** Defense of essay | 2 | 2 | PC-3.1 |
| **1.18** | **Defense of essays** **(Pr).** Defense of essay | 2 | 2 | PC-3.1 |
| **1.19** | **Defense of essays** **(Pr).** Defense of essay | 2 | 2 | PC-3.1 |
| **1.20** | **Defense of essays** **(Pr).** Defense of essay | 2 | 2 | PC-3.1 |
| **1.21** | **Defense of essays** **(Pr).** Defense of essay | 2 | 2 | PC-3.1 |
| **1.22** | **Defense of essays** **(Pr).** Defense of essay | 2 | 2 | PC-3.1 |
| **1.23** | **Defense of essays** **(Pr).** Defense of essay | 2 | 2 | PC-3.1 |
| **1.24** | **Solution of the control work (Pr).** Control work on the discipline section | 2 | 2 | PC-3.1 |
| **1.25** | **Laboratory work 1** **(LW).** «Optical methods of nanostructure research» part 1 | 2 | 4 (including 2 for practicing practical skills) | PC-3.1 |
| **1.26** | **Laboratory work 2** **(LW).** «Optical methods of nanostructure research» part 2 | 2 | 4 (including 2 for practicing practical skills) | PC-3.1 |

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| **1.27** | **Laboratory work 3** **(LW).** «Scanning electron microscopy methods for the study of nanoobjects» part 1 | 2 | 4 (including 2 for practicing practical skills) | PC-3.1 |
| **1.28** | **Laboratory work 4** **(LW).** «Scanning electron microscopy methods for the study of nanoobjects» part 2 | 2 | 4 (including 2 for practicing practical skills) | PC-3.1 |
| **1.29** | **Preparation for classroom classes (IWS).** Control questions | 2 | 32 | PC-3.1 |
| **1.30** | **Homework (IWS).** Writing a review on the topic | 2 | 30 | PC-3.1 |
| **2. Intermediate certification (Test)** | | | | |
| **2.1** | **Preparation for the intermediate certification (Test).** | 2 | 17,75 | PC-3.1 |
| **2.2** | **Contact work with the teacher during the intermediate certification (CWC).** | 2 | 0,25 | PC-3.1 |
| **3. System Integration** | | | | |
| **3.1** | **Lecture** **9.** **Optical fibers with photonic crystal structure (Lec).** Nanophotonics. Photonic crystals. Optical fibers with a photonic crystal structure (PCF). Manufacturing technology of optical fibers with PCF. Fiber light guides with Bragg gratings. Sensors based on optical waveguides with a photonic crystal structure. | 3 | 2 | PC-3.2 |
| **3.2** | **Lecture** **10.** **Periodic domain structures (PDS) in ferroelectric crystals (Lec).** Periodic Domain structures (PDS). Methods of formation of induced domains and periodic domain structures in ferroelectrics. Propagation and generation of optical waves in PDS waves. Nonlinear optical effects in PDS. | 3 | 2 | PC-3.2 |
| **3.3** | **Lecture** **11.** **Nanomachines and nano devices (Lec).** Microelectromechanical systems (MEMS). Nanoelectromechanical systems (NEMS). Molecular and supramolecular switches. Materials and technologies of the future. Biomaterials. Bionic and self-assembling materials. Nanoscale materials and assembly. | 3 | 2 | PC-3.2 |
| **3.4** | **Lecture** **12.** **Nanomaterials for information technology (Lec).** Internal nanomemory. External memory. Nanocapacitors. Nanoprocessor. Display technique. | 3 | 2 | PC-3.2 |
| **3.5** | **Lecture** **13.** **Quantum materials. (Lec).** Magnets. Superconductors. Metamaterials. Plasmonics. | 3 | 2 | PC-3.2 |

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| **3.6** | **Lecture** **14.** **Development of integration technologies and standards (Lec).** Technical standards for the interaction of software components. Methodology of open systems. Object-oriented interaction standards. | | 3 | 2 | PC-3.2 | |
| **3.7** | **Lecture** **15.** **Description of the architecture of integration solutions using templates** **(Lec).** The role of templates in IP design tasks.  Using templates to document expert knowledge at the design stage of an integration solution. Template description languages. | | 3 | 2 | PC-3.2 | |
| **3.8** | **Lecture** **16.** **Service-oriented integration (Lec).** A service approach to data management. Data services and application services. The level of integration. Security and service management. Basic templates. | | 3 | 2 | PC-3.2 | |
| **3.9** | **Oral interview (Pr).** Control questions | | 3 | 2 | PC-3.2 | |
| **3.10** | **Oral interview (Pr).** Control questions | | 3 | 2 | PC-3.2 | |
| **3.11** | **Oral interview (Pr).** Control questions | | 3 | 2 | PC-3.2 | |
| **3.12** | **Oral interview (Pr).** Control questions | | 3 | 2 | PC-3.2 | |
| **3.13** | **Oral interview (Pr).** Control questions | | 3 | 2 | PC-3.2 | |
| **3.14** | **Oral interview (Pr).** Control questions | | 3 | 2 | PC-3.2 | |
| **3.15** | **Oral interview (Pr).** Control questions | | 3 | 2 | PC-3.2 | |
| **3.16** | **Oral interview (Pr).** Control questions | | 3 | 2 | PC-3.2 | |
| **3.17** | **Defense of essays** **(Pr).** Defense of essay | | 3 | 2 | PC-3.2 | |
| **3.18** | **Defense of essays** **(Pr).** Defense of essay | | 3 | 2 | PC-3.2 | |
| **3.19** | **Defense of essays** **(Pr).** Defense of essay | | 3 | 2 | PC-3.2 | |
| **3.20** | **Defense of essays** **(Pr).** Defense of essay | | 3 | 2 | PC-3.2 | |
| **3.21** | **Defense of essays** **(Pr).** Defense of essay | | 3 | 2 | PC-3.2 | |
| **3.22** | **Defense of essays** **(Pr).** Defense of essay | | 3 | 2 | PC-3.2 | |
| **3.23** | **Defense of essays** **(Pr).** Defense of essay | | 3 | 2 | PC-3.2 | |
| **3.24** | **Solution of the control work (Pr).** Control questions | | 3 | 2 | PC-3.2 | |
| **3.25** | **Preparation for classroom classes (IWS).** Control questions | | 3 | 30 | PC-3.2 | |
| **3.26** | **Homework (IWS).** Writing a review on the topic | | 3 | 30 | PC-3.2 | |
| **4. Intermediate certification (exam)** | | | | | | |
| **4.1** | **Preparation for the intermediate certification (Exam).** | | 3 | 33,65 | PC-3.2 | |
| **4.2** | **Contact work with the teacher during the intermediate certification (CWC).** | | 3 | 2,35 | PC-3.2 | |
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| **5. EVALUATION MATERIALS** | | | | | | |
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| **5.1. List of competencies** | | | | | | |

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| List of competencies, the development of which the study of the discipline is aimed at «Innovative materials and system integration for information technologies», with an indication of the results of their formation in the process of mastering the educational program, presented in paragraph 3 of this work program | | |
| **5.2. Typical control questions and tasks** | | |
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| The main classes of nanomaterials and nanotechnologies.  The main classes of nanomaterials and nanotechnologies.  Nanomaterials.  Classification and methods of obtaining nanoclusters (quantum dots) and nanostructures (quantum wires).  Physical chemical and technological features of various types of nanostructured materials.  Carbon nanoclusters, nanostructures, and nanomaterials  The shape and structure of nanotubes, methods of production. Properties of nanotubes.  Application of nanotubes.  Graphene. Features. Application.  Bulk nanostructured materials  Solid-state nanoclusters and nanostructures, thin films, Thermal and mechanical properties. Volumetric nanostructured materials for photonics. Optical properties.  Electrical and magnetic properties of nanosystems and nanomaterials.  Electrical conductivity of three-dimensional, two-dimensional and one-dimensional nanostructures.  Magnetization of nanoclusters and nanostructures. The effect of giant  magnetoresistance.  Self-assembly and catalysis. Surface effects.  The process of self-assembly. Monolayers. The surface area of nanoparticles. Surface effects. Adsorption.  Applications of nanomaterials and nanotechnologies  Classification of low-dimensional systems quantum wells, wires and dots,  Optical properties of quantum dots (0D systems)  Optical properties of nanoclusters of nanosystems and nanomaterials.  Quantum dot lasers.  Optical fibers with a photonic crystal structure.  Photonic crystals  Optical fibers with a photonic crystal structure (PCF).  Manufacturing technology of optical fibers with photonic crystal structure.  The use of PCF.  Formation of the photonic band gap by submicron Bragg gratings.  Fiber light guides with Bragg gratings.  Sensors based on optical waveguides with a photonic crystal structure.  Periodic domain structures (PDS) in ferroelectric crystals  Periodic domain structures (PDS) in ferroelectric crystals  Methods of formation of induced domains and periodic domain structures in ferroelectrics  Propagation and generation of optical waves in PDS waves.  Nonlinear optical effects in PDS.  The main stages of development of IT management technologies.  The basic principles of process-oriented IT management.  Composition and interrelations of the cost management process with other IT service management processes  Composition and interrelations of the Capacity Management process with other IT service management processes  The continuity management process. Advantages and problems of the process.  The security management process. Goals and benefits of the process  Enterprise information security system (system tasks, protection objects) | | |

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| The main sources of threats and types of violations in the field of information security.  The relevance of the task of integration, combining computing, information and  communication resources.  Evolution of approaches to building an integrated corporate system. The task of  preserving investments in IT.  The main types of integration tasks. Integration difficulties.  Distributed applications. The concepts of a host and an intermediate environment (middleware).  Basic models of distributed systems architecture. Non-functional requirements that affect the choice of architecture of a distributed information system.  Methodology of "open systems" and the problem of integration.  Main functionality: modeling and management of the structure and  quality of information, standardization, data merging and correction, data transformation and enrichment, replication, virtualization and information delivery.  The concept of "big data" and its impact on the architecture of integration solutions | | | | | |
| **5.3. Fund of evaluation Materials** | | | | | |
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| A complete list of evaluation materials is provided in the Appendix 1. | | | | | |
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| **6. MATERIAL, TECHNICAL, EDUCATIONAL AND METHODOLOGICAL SUPPORT OF THE DISCIPLINE (MODULE)** | | | | | |
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| **6.1. MATERIAL AND TECHNICAL SUPPORT OF THE DISCIPLINE (МОДУЛЯ)** | | | | | |
| **Name of premises** | | | | **List of main equipment** | |
| Classroom for lectures and seminars, group and individual consultations, ongoing monitoring and intermediate certification | | | | Multimedia equipment, specialized furniture, sets of demonstration equipment and educational and visual aids that provide thematic illustrations. | |
| A room for independent work of students | | | | Computer equipment with the ability to connect to the Internet and provide access to the electronic information and educational environment of the organization. | |
| Specialized educational and scientific laboratory «Ultrafast dynamics of ferroics» | | | | Optical spectroscopy of the magneto-optical Kerr effect,  Synchronous Broadband tunable femtosecond pulse generator,  Femtosecond laser tunable system | |
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| **6.2. LIST OF SOFTWARE** | | | | | |
| 1. |  | Microsoft Windows. Contract No. 32009183466 from 02.07.2021. | | | |
| 2. |  | Microsoft Office. Contract No. 32009183466 from 02.07.2021. | | | |
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| **6.3. RECOMMENDED LITERATURE** | | | | | |
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| **6.3.1. Basic literature** | | | | | |
| 1. |  | Plomod'yalo R. L. Nanotekhnologii. Poluchenie, metody kontrolya i mezhdunarodnaya standartizaciya nanomaterialov [Electronic resource]:uchebnoe posobie. - Krasnodar: KubGTU, 2018. - 135 s.– Access mode: https://e.lanbook.com/book/151171 | | | |
| 2. |  | Ignatov A. N. Optoelektronika i nanofotonika [Electronic resource]:. - Sankt- Peterburg: Lan', 2020. - 596 s. – Access mode: https://e.lanbook.com/book/133479 | | | |
| 3. |  | Pryahin E. I., Vologzhanina S. A., Petkova A. P., Ganzulenko O. YU. Nanomaterialy i nanotekhnologii [Electronic resource]:uchebnik dlya vuzov. - Sankt-Peterburg: Lan', 2020. - 372 s. – Access mode: https://e.lanbook.com/book/149303 | | | |

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| 4. |  | Rogov V. A. Tekhnologiya konstrukcionnyh materialov. Nanotekhnologii [Electronic resource]:Uchebnik dlya vuzov. - Moscow: YUrajt, 2020. - 190 s – Access mode: https://urait.ru/bcode/451888 | | | | |
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| **6.3.2. Additional literature** | | | | | | |
| 1. |  | Ryzhonkov D. I., Lyovina V. V., Dzidziguri E. L. Nanomaterialy:Ucheb. posobie. - M.: BINOM. Laboratoriya znanij, 2012. - 365 s. | | | | |
| 2. |  | Martines-Duart Dzh. M., Martin-Palma R. Dzh., Agullo-Rueda F. Nanotekhnologii dlya mikro- i optoelektroniki:Per. s angl.. - M.: Tekhnosfera, 2009. - 368 s. | | | | |
| 3. |  | Pul CH., Ouens F. Nanotekhnologii:[Ucheb. posobie dlya vuzov]. - M.: Tekhnosfera, 2005. - 334 s. | | | | |
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| **6.4. RECOMMENDED LIST OF MODERN PROFESSIONAL DATABASES AND INFORMATION REFERENCE SYSTEMS** | | | | | | |
| 1. |  | Materials Science Information Portal http://www.materialstoday.com | | | | |
| 2. |  | Website of the PTI Department of Nanoelectronics https://fks.mirea.ru | | | | |
| 3. |  | News and analytical portal "Vremya elektroniki "  http://www.russianelectronics.ru | | | | |
| 4. |  | Journal «Nano- and Microsystem Technology»  http://www.microsystems.ru | | | | |
| 5. |  | An international resource for the search and exchange of scientific publications  https://www.researchgate.net | | | | |
| 6. |  | Elektronika NTB - scientific and technical journal  http://www.electronics.ru | | | | |
| 7. |  | Information and reference portal of scientific publications of domestic and foreign authors «Google Academy»  https://www.scholar.google.ru | | | | |
| 8. |  | Russian Technological Journal  https://www.rtj.mirea.ru | | | | |
| 9. |  | Magazine portal of the A.F. Ioffe Institute of Physics and Technology  https://www.journals.ioffe.ru | | | | |
| 10. |  | Information portal of the International Citation System Scopus  https://www.scopus.com | | | | |
| 11. |  | Information portal of the International Citation System «Web of Science”  https://www.apps.webofknowledge.com | | | | |
| 12. |  | Foundation for the Promotion of Innovation  http://www.fasie.ru | | | | |
| 13. |  | Ministry of Science and Higher Education of the Russian Federation  https://www.minobrnauki.gov.ru | | | | |
| 14. |  | Scientific Electronic Library http://www.elibrary.ru | | | | |
| 15. |  | Information portal of the Russian Science Foundation http://www.rscf.ru | | | | |
| 16. |  | Russian Foundation for Basic Research https://www.rfbr.ru | | | | |
| 17. |  | Information portal «Popular nanotechnologies» http://www.popnano.ru | | | | |
| 18. |  | Nanometer - Nanotechnology community http://www.nanometer.ru | | | | |
| 19. |  | NanoNewsNet.ru- non-commercial on-line publication dedicated to the nanoindustry http://www.old.nanonewsnet.ru | | | | |
| 20. |  | Electronic fund of legal and regulatory technical documentation Tekhnoexpert http://www.docs.cntd.ru | | | | |
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| **6.5. METHODICAL INSTRUCTIONS FOR STUDENTS STUDYING THE DISCIPLINE (MODULE)** | | | | | | |
| The student’s independent work is aimed at preparing for academic classes and at developing knowledge, skills and abilities provided for in the discipline program.  In accordance with the curriculum, the discipline may include Lectures, practical classes and Laboratory work, as well as the execution and defense of a course project (work). Successful study of the discipline requires attending all types of classes, completing teacher assignments and familiarization with basic and additional literature. Depending on the activities provided for in the curriculum and section 4 of this program, the student chooses methodological guidelines for independent work from the ones listed below.  When preparing for lecture classes, students need to:  before the next lecture, it is necessary to review the summary of the material of the previous Lectures. If you have difficulties in perceiving the material, you should refer to the main literary sources. If it was not possible to understand the material again, then contact the lecturer (according to the schedule of his consultations) or the teacher in practical classes.  Practical classes complete the study of the most important topics of the discipline. They serve to consolidate the studied material, develop the skills and abilities of preparing reports, messages, gaining experience in oral public speeches, conducting discussions, argumentation and defending the propositions put forward, as well as to monitor the degree of readiness of students in the discipline being studied by the teacher.  When preparing for a practical lesson, students have the opportunity to use the advice of a teacher.  When preparing for practical classes, students need to:  bring with you the literature recommended by the teacher for a specific lesson;  before the next practical lesson on the recommended literary sources, work out the theoretical material corresponding to the topic of the lesson;  at the beginning of classes, ask the teacher questions about the material that caused difficulties in understanding and mastering it when solving tasks set for independent solution;  during the seminar, give specific, clear answers to the substance of the questions;  at the training session, bring each task to the final solution, demonstrate an understanding of the calculations (analyses, situations), in case of difficulties, contact the teacher.  Students who have missed classes (regardless of the reasons), who do not have a written solution to problems or are not prepared for this practical lesson, are recommended to come to the teacher’s consultation no later than 2 weeks and report on the topic studied in the lesson.  The methodological guidelines necessary for studying and passing the discipline are given as part of the educational program. | | | | | | |
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| **6.6. METHODOLOGICAL RECOMMENDATIONS FOR THE TRAINING OF PERSONS WITH LIMITED HEALTH OPPORTUNITIES AND THE DISABLED** | | | | | | |
| The development of the discipline by students with disabilities can be organized both jointly with other students and in separate groups. Special conditions are assumed for students with disabilities to receive education.  The teaching staff gets acquainted with the psychological and physiological characteristics of students with disabilities and persons with disabilities, individual rehabilitation programs for the disabled (if available). If necessary, additional teaching support is provided by tutors, psychologists, social workers, trained assistants.  In accordance with the methodological recommendations of the Ministry of Education and Science of the Russian Federation (approved April 8, 2014 N AK-44/05vn), the course is supposed to use socially active and reflective teaching methods, technologies of socio-cultural rehabilitation in order to assist in establishing full-fledged interpersonal relationships with other students, creating | | | | | | |

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| a comfortable psychological climate in the student group. Selection and development of educational materials are made taking into account the provision of material in various forms: auditory, visual, using special technical means and information systems.  Mediamaterials should also be used and adapted taking into account the individual characteristics of the training of persons with disabilities.  The development of the discipline by persons with disabilities is carried out using general and special purpose teaching tools (personal and collective use). Material and technical support provides for the adaptation of classrooms to the needs of persons with disabilities.  The form of certification for students with disabilities is established taking into account individual psychophysical characteristics. For students with HIA, an accessible form of assignment of assessment tools is provided, namely:  - in printed or electronic form (for persons with disorders of the musculoskeletal system);  - in printed or electronic form with enlarged font and contrast (for persons with hearing, speech, vision impairments);  - reading the task aloud by the assistant (for visually impaired persons).  Students with disabilities have increased time to prepare answers to control questions. For such students, an accessible form of providing answers to tasks is provided, namely:  - written on paper or a set of answers on a computer (for persons with hearing and speech impairments);  - choosing an answer from possible options using the services of an assistant (for people with musculoskeletal disorders);  - oral interview (for persons with visual impairments, musculoskeletal system).  If necessary, for students with disabilities, the procedure for evaluating learning outcomes can be carried out in several stages. | | |

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| Federal State Budget Educational Institution of Higher Education  «MIREA – Russian Technological University» | | | | | | | | | | | | | | | | | | | | | |
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| Working program of the discipline (module) | | | | | | | | | | | | | | | | | | | | | |
| **Quantum materials and quantum operation for information technologies** | | | | | | | | | | | | | | | | | | | | | |
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|  | Department leading the training | | | | | |  |  | **Department of Nanoelectronics** | | | | | | | | | | | | |
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|  | Direction of training | | | | | | |  | **11.04.04 Electronics and nanoelectronics** | | | | | | | | | | | | |
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|  | Profile | | | | | | |  | **Engineering of modern materials for information technology, renewable energy and sensing** | | | | | | | | | | | | |
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|  | Qualification | | | | |  |  |  | **Master** | | | | | | | | | | | | |
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|  | Form of education | | | | |  |  |  | **Full-time** | | | | | | | | | |  |  |  |
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|  | Total labor intensity | | | |  |  |  |  | **4 credits** | | | | | | | | | |  |  |  |
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| **Distribution of discipline hours and forms of intermediate certification by semesters** | | | | | | | | | | | | | | | | | | | | | |
| Semester | | Credits | Distribution of hours | | | | | | | | | | | | | | | Forms of intermediate attestation | | |  |
| Total | Lectures | | | | Laboratory work | | | Practical classes | Independent work of students | | Contact work during practice and (or) certification | | | Control of training |  |
| 3 | | 4 | 144 | 16 | | | | 0 | | | 16 | 76 | | 2,25 | | | 33,75 | Test, Coursework | | |  |
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| The program was made by: |  |  |  |  |
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| *Ph.D. Physics and Mathematics, Associate Professor, I. Gladyshev \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_* | | | | |
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| Working program of the discipline | | |  |  |
| **Quantum materials and quantum operation for information technologies** | | | | |
|  |  |  |  |  |
| it is developed in accordance with FSES HE: | | |  |  |
| Federal State Educational Standard of Higher Education - Magistracy in the Direction of training 11.04.04 Electronics and nanoelectronics (order of the Ministry of Science and Higher Education of the Russian Federation from 22.09.2017. № 959) | | | | |
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| it is based on the curriculum: | | |  |  |
| Direction of training: 11.04.04 Electronics and nanoelectronics  Profile: «Engineering of modern materials for information technology, renewable energy and sensing» | | | | |
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| The working program was approved at the meeting of the department | | | | |
| **Department of Nanoelectronics** | | | | |
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| Minutes of meeting from 02.03.2021 № 3  Head of the Department A. Sigov \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ | | | | |

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| **Approval of the WPD for execution in the next academic year** | | | | |
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| The working program was revised, discussed and approved for execution in the 2022-2023 academic year at a meeting of the department | | | | |
| **Department of Nanoelectronics** | | | | |
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|  | Minutes of meeting from \_\_ \_\_\_\_\_\_\_\_\_\_ 2022. № \_\_  Head of the Department \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ | | | |
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| **Approval of the WPD for execution in the next academic year** | | | | |
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| The working program was revised, discussed and approved for execution in the 2023-2024 academic year at a meeting of the department | | | | |
| **Department of Nanoelectronics** | | | | |
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|  | Minutes of meeting from \_\_ \_\_\_\_\_\_\_\_\_\_ 2023. № \_\_  Head of the Department \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ | | | |
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| **Approval of the WPD for execution in the next academic year** | | | | |
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| The working program was revised, discussed and approved for execution in the 2024-2025 academic year at a meeting of the department | | | | |
| **Department of Nanoelectronics** | | | | |
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|  | Minutes of meeting from \_\_ \_\_\_\_\_\_\_\_\_\_ 2024. № \_\_  Head of the Department \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ | | | |
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| **Approval of the WPD for execution in the next academic year** | | | | |
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| The working program was revised, discussed and approved for execution in the 2025-2026 academic year at a meeting of the department | | | | |
| **Department of Nanoelectronics** | | | | |
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|  | Minutes of meeting from \_\_ \_\_\_\_\_\_\_\_\_\_ 2025. № \_\_  Head of the Department \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ | | | |
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| **1. OBJECTIVES OF MASTERING THE DISCIPLINE (MODULE)** | | | | | |
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| The discipline «Quantum materials and quantum operation for information technologies» aims to contribute to the formation of students’ competencies, provided by this work program in accordance with the requirements of FSES HE in the direction of training 11.04.04 Electronics and nanoelectronics, taking into account the specifics of the profile – «Engineering of modern materials for information technology, renewable energy and sensing». | | | | | |
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| **2. PLACE OF DISCIPLINE (MODULE) IN THE STRUCTURE OF THE EDUCATIONAL PROGRAM** | | | | | |
|  | Direction of training: |  | 11.04.04 Electronics and nanoelectronics | | |
|  |
|  | Profile: |  | Engineering of modern materials for information technology, renewable energy and sensing | | |
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|  | Block: |  | Disciplines (modules) | | |
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|  | Part: |  | Part of the curriculum formed by the participants of educational | | |
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|  | Total labor intensity: |  | 4 credits (144 academic hours). | | |
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| **3. THE STUDENT’S COMPETENCIES FORMED AS A RESULT OF MASTERING THE DISCIPLINE (MODULE)** | | | | | |
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| As a result of mastering the practice, the student must master the following competencies: | | | | | |
| **PC-1** - Capable to apply in-depth knowledge of the structure, physical, physicochemical properties, the purpose of nanomaterials and nanostructures, and methods of measuring their parameters | | | | | |
| **PC-3** - Capable of determining possible physical implementation options, physical and mathematical models of micro- and nanosystems and using software tools for their design and modeling | | | | | |
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| **PLANNED RESULTS OF TRAINING IN THE DISCIPLINE (MODULE), CHARACTERIZING THE FORMATION OF COMPETENCIES** | | | | | |
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| **PC-1 : Capable to apply in-depth knowledge of the structure, physical, physicochemical properties, the purpose of nanomaterials and nanostructures, and methods of measuring their parameters** | | | | | |
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| **PC-1.1: Applies in-depth knowledge of the structure, physical, physicochemical properties, the purpose of nanomaterials and nanostructures, and methods for measuring their parameters in the field of electronics** | | | | | |
| **To know:** | | | | | |
| - what quantum mechanical effects are used in electronics | | | | | |
| **Be able to:** | | | | | |
| - apply physical laws and the corresponding physical and mathematical apparatus to solve simple typical problems of quantum mechanics | | | | | |
| **Possess:** | | | | | |
| - skills of using the laws of physics and mathematics in solving practical problems | | | | | |
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| **PC-3 : Capable of determining possible physical implementation options, physical and mathematical models of micro- and nanosystems and using software tools for their design and modeling** | | | | | |

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| **PC-3.1: Defines possible variants of physical and mathematical models in the field of nanoelectronics** | | | | | | |
| **To know:** | | | | | | |
| - basic principles of drawing up computational models of physical systems | | | | | | |
| **Be able to:** | | | | | | |
| - apply knowledge of quantum mechanical effects for qualitative analysis of computational models of physical systems | | | | | | |
| **Possess:** | | | | | | |
| - skills of drawing up algorithms for computational models of physical systems | | | | | | |
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| **AS A RESULT OF STUDYING THE DISCIPLINE (MODULE), THE STUDENT MUST** | | | | | | |
|  |  |  |  |  |  |  |
| **To know:** | | | | | | |
| - basic principles of drawing up computational models of physical systems | | | | | | |
| - what quantum mechanical effects are used in electronics | | | | | | |
| **Be able to:** | | | | | | |
| - apply knowledge of quantum mechanical effects for qualitative analysis of computational models of physical systems | | | | | | |
| - apply physical laws and the corresponding physical and mathematical apparatus to solve simple typical problems of quantum mechanics | | | | | | |
| **Possess:** | | | | | | |
| - skills of drawing up algorithms for computational models of physical systems | | | | | | |
| - skills of using the laws of physics and mathematics in solving practical problems | | | | | | |
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| **4. STRUCTURE AND CONTENT OF THE DISCIPLINE (MODULE)** | | | | | | |
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| During the training sessions, the organization ensures the development of students’ teamwork skills, interpersonal communication, decision-making and leadership qualities. | | | | | | |
| **Code** | **Name of sections and topics /type of classes/** | | **Semester** | **Academic Hours** | **Competencies** | |
| **1. Quantum materials and quantum operations** | | | | | | |
| **1.1** | **Lecture** **1.** **Introduction. Quantum materials.** **(Lec).** The concept of "Quantum materials". Strong electronic correlations. Superconductors. Magnets. Topological insulators. Graphene. Quantum entanglement. Chiral magnetic effect. | | 3 | 2 | PC-1.1, PC-3.1 | |
| **1.2** | **Lecture2.** **Photonic crystals.** **(Lec).** Determination of photonic crystals. The concept of a forbidden zone. Classification of photonic crystals according to the dimension of periodicity and depending on the width of the forbidden and allowed zones. Propagation of light in photonic crystals. Reflection and transmission spectra. | | 3 | 2 | PC-1.1, PC-3.1 | |

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| **1.3** | **Lecture** **3.** **Finite difference method in the time domain (FDTD)** **(Lec).** Modeling of photonic crystal-based devices using the FDTD method. Statement of the problem for calculating the distribution of the field. The difference form of Maxwell's equations. Definition of dialectical function. Determination of initial and boundary conditions. Stability of the FDTD method. | | 3 | 2 | PC-1.1, PC-3.1 | |
| **1.4** | **Lecture** **4.** **Density of photonic states (Lec).** The concept of density of states. Relation of the density of states with dispersion relations in photonic crystals. Van Hove points. Complete and incomplete forbidden zones. Examples of state densities for various photonic crystals. | | 3 | 2 | PC-1.1, PC-3.1 | |
| **1.5** | **Lecture** **5.** **Plasmonics** **(Lec).** Plasmons. Plasmon resonance. Nanoplasmonics. Surface plasmon polariton. A flat plasmon waveguide. Plasmon nanolaser. Plasmonstore (plasmon switch). Nanoplasmonics devices. Polaritons. | | 3 | 2 | PC-1.1, PC-3.1 | |
| **1.6** | **Lecture** **6.** **Metamaterials** **(Lec).** Definition of metamaterials. "Right" and "Left" isotropic media. Optics of materials with a negative refractive index. Superlens. Optical plasmonic metamaterials. Application of optical metamaterials. Metasurfaces. Hybrid nanoantennas. | | 3 | 2 | PC-1.1, PC-3.1 | |
| **1.7** | **Lecture** **7.** **Quantum computing (Lec).** Bits and qubits. Cat Vectors. The Bloch sphere is a visualization of a qubit. Confused states. Quantum circuits. Logic elements acting on 1 qubit. Pauli valves. The phase valve. The Hadamard valve. Logic elements acting on several qubits. The two-qubit valve is NOT. Toffoli and Fredkin valve. Distributed circuits: controlled U-valve, bit exchange circuit, "copy" circuit. Bell's logic element. Super-dense coding. The relationship between classical quantum computing. | | 3 | 2 | PC-1.1, PC-3.1 | |
| **1.8** | **Lecture** **8.** **The Limits of quantum Computers.** **(Lec).** Limitations of the computational capabilities of quantum computers arising from the quantum-mechanical nature of computing elements. Sources of quantum errors. A measure of decoherence. Classic noise. Phase errors. Interqubit interaction. Loss of coherence of the quantum state. | | 3 | 2 | PC-1.1, PC-3.1 | |
| **1.9** | **Performing practical tasks (Pr).** Superconductors in a magnetic field. | | 3 | 2 | PC-1.1, PC-3.1 | |

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| **1.10** | **Performing practical tasks (Pr).** Photon forbidden zone, calculation methods | | 3 | 2 | PC-1.1, PC-3.1 | |
| **1.11** | **Performing practical tasks (Pr).** Finite difference method, comparison with finite element method | | 3 | 2 | PC-1.1, PC-3.1 | |
| **1.12** | **Performing practical tasks (Pr).** Optical modes. Representation as points in phase space. | | 3 | 2 | PC-1.1, PC-3.1 | |
| **1.13** | **Performing practical tasks (Pr).** Plasma of solids | | 3 | 2 | PC-1.1, PC-3.1 | |
| **1.14** | **Oral interview (Pr).** Control questions | | 3 | 2 | PC-1.1, PC-3.1 | |
| **1.15** | **Oral interview (Pr).** Control questions | | 3 | 2 | PC-1.1, PC-3.1 | |
| **1.16** | **Oral interview (Pr).** Control questions | | 3 | 2 | PC-1.1, PC-3.1 | |
| **1.17** | **Execution of coursework (project) (IWS).** Coursework development | | 3 | 46 | PC-1.1, PC-3.1 | |
| **1.18** | **Homework (IWS).** Writing a review on a selected topic | | 3 | 20 | PC-1.1 | |
| **1.19** | **Preparation for classroom classes (IWS).** Control questions | | 3 | 10 | PC-1.1, PC-3.1 | |
| **2. Intermediate certification (Test)** | | | | | | |
| **2.1** | **Preparation for the intermediate certification (Test).** | | 3 | 16 | PC-1.1, PC-3.1 | |
| **2.2** | **Contact work with the teacher during the intermediate certification (CWC).** | | 3 | 0,25 | PC-1.1, PC-3.1 | |
| **3. Intermediate certification (Coursework)** | | | | | | |
| **3.1** | **Preparation for the intermediate certification (КР).** | | 3 | 17,75 | PC-1.1, PC-3.1 | |
| **3.2** | **Contact work with the teacher during the intermediate certification (CWC).** | | 3 | 2 | PC-1.1, PC-3.1 | |
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| **5. EVALUATION MATERIALS** | | | | | | |
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| **5.1. List of competencies** | | | | | | |
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| List of competencies, the development of which the study of the discipline is aimed at «Quantum materials and quantum operation for information technologies», with an indication of the results of their formation in the process of mastering the educational program, presented in paragraph 3 of this work program | | | | | | |
| **5.2. Typical control questions and tasks** | | | | | | |
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| Classification of photonic crystals.  Photonic crystals in nature.  Physical features of periodic electromagnetic structures.  The band structure of photonic crystals. The density of electromagnetic field states in photonic crystals.  The concept of a complete forbidden zone and a pseudozone. Physical meaning  Localization of light.  Spontaneous emission in photonic crystals.  Photonic crystals as a base for optical computer science devices.  Optical effects at the zone boundary. | | | | | | |

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| Synthesis of microspheres from silicon dioxide.  Porosity of photonic crystals based on opals.  Methods of formation of ordered structures of artificial opals.  Forbidden zone of artificial opals.  The concept of an effective refractive index.  Methods of diagnostics and research of synthesized photonic crystals.  The difference between photonic crystals and metamaterials.  What is "slow" light?  Superconductors of the I and II kind in a magnetic field.  Ferro-, ferri- and antiferromagnets.  Basic properties of graphene.  The concept of the forbidden zone in photonic crystals.  The essence of the FDTD method.  What is the difference between the finite difference method and the finite element method?  The difference form of Maxwell's equations.  Stability of the FDTD method.  The concept of density of states.  Van Hove points.  Complete and incomplete forbidden zones.  Definition of metamaterials.  Generalized Snellius law.  Application of optical metamaterials for wave flow around objects.  Negative refractive index  Qubits.  What are Pauli valves.  What is a phase valve?  What is the Hadamard valve.  Phase errors in quantum computing.  The influence of the intercubit interaction on the stability of the solution in quantum computing.  Loss of coherence of the quantum state. | | | | | |
| **5.3. Fund of evaluation Materials** | | | | | |
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| A complete list of evaluation materials is provided in the Appendix 1. | | | | | |
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| **6. MATERIAL, TECHNICAL, EDUCATIONAL AND METHODOLOGICAL SUPPORT OF THE DISCIPLINE (MODULE)** | | | | | |
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| **6.1. MATERIAL AND TECHNICAL SUPPORT OF THE DISCIPLINE (МОДУЛЯ)** | | | | | |
| **Name of premises** | | | | **List of main equipment** | |
| Classroom for lectures and seminars, group and individual consultations, ongoing monitoring and intermediate certification | | | | Multimedia equipment, specialized furniture, sets of demonstration equipment and educational and visual aids that provide thematic illustrations. | |
| A room for independent work of students | | | | Computer equipment with the ability to connect to the Internet and provide access to the electronic information and educational environment of the organization. | |
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| **6.2. LIST OF SOFTWARE** | | | | | |
| 1. |  | Microsoft Windows. Contract No. 32009183466 from 02.07.2021. | | | |
| 2. |  | Microsoft Office. Contract No. 32009183466 from 02.07.2021. | | | |
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| **6.3. RECOMMENDED LITERATURE** | | | | | |

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| **6.3.1. Basic literature** | | | | |
| 1. |  | Ignatov A. N. Optoelektronika i nanofotonika [Electronic resource]: - Sankt- Peterburg: Lan', 2020. - 596 s.– Access mode: https://e.lanbook.com/book/133479 | | |
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| **6.3.2. Additional literature** | | | | |
| 1. |  | Mishina E. D., SHerstyuk N. E., Evdokimov A. A., i dr., A. Sigov Metody polucheniya i issledovaniya nanomaterialov i nanostruktur:uchebnoe posobie dlya vuzov. - M.: BINOM. Laboratoriya znanij, 2013. - 184 s. | | |
| 2. |  | Gavrilov A. V., Doskolovich L. L., Kovalev A. A., i dr., Sojfer V. A. Difrakcionnaya nanofotonika. - M.: FIZMATLIT, 2011. - 679 s. | | |
| 3. |  | Novotnyj L., Hekht B. Osnovy nanooptiki: [Uchebnik]. - M.: FIZMATLIT, 2011. - 482 s. | | |
| 4. |  | Klimov V. V. Nanoplazmonika: - M.: FIZMATLIT, 2010. - 480 s. | | |
| **6.4. RECOMMENDED LIST OF MODERN PROFESSIONAL DATABASES AND INFORMATION REFERENCE SYSTEMS** | | | | |
| 1. |  | Materials Science Information Portal http://www.materialstoday.com | | |
| 2. |  | Website of the PTI Department of Nanoelectronics https://fks.mirea.ru | | |
| 3. |  | News and analytical portal "Vremya elektroniki "  http://www.russianelectronics.ru | | |
| 4. |  | Journal «Nano- and Microsystem Technology»  http://www.microsystems.ru | | |
| 5. |  | An international resource for the search and exchange of scientific publications  https://www.researchgate.net | | |
| 6. |  | Elektronika NTB - scientific and technical journal  http://www.electronics.ru | | |
| 7. |  | Information and reference portal of scientific publications of domestic and foreign authors «Google Academy»  https://www.scholar.google.ru | | |
| 8. |  | Russian Technological Journal  https://www.rtj.mirea.ru | | |
| 9. |  | Magazine portal of the A.F. Ioffe Institute of Physics and Technology  https://www.journals.ioffe.ru | | |
| 10. |  | Information portal of the International Citation System Scopus  https://www.scopus.com | | |
| 11. |  | Information portal of the International Citation System «Web of Science”  https://www.apps.webofknowledge.com | | |
| 12. |  | Foundation for the Promotion of Innovation  http://www.fasie.ru | | |
| 13. |  | Ministry of Science and Higher Education of the Russian Federation  https://www.minobrnauki.gov.ru | | |
| 14. |  | Natural Science educational Portal http://www.en.edu.ru | | |
| 15. |  | Scientific Electronic Library http://www.elibrary.ru | | |
| 16. |  | Information portal of the Russian Science Foundation http://www.rscf.ru | | |
| 17. |  | Russian Foundation for Basic Research https://www.rfbr.ru | | |
| 18. |  | Information portal «Popular nanotechnologies» http://www.popnano.ru | | |
| 19. |  | Nanometer - Nanotechnology community http://www.nanometer.ru | | |
| 20. |  | NanoNewsNet.ru- non-commercial on-line publication dedicated to the nanoindustry http://www.old.nanonewsnet.ru | | |

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| 21. |  | Electronic fund of legal and regulatory technical documentation Tekhnoexpert http://www.docs.cntd.ru | | |
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| **6.5. METHODICAL INSTRUCTIONS FOR STUDENTS STUDYING THE DISCIPLINE (MODULE)** | | | | |
| The student’s independent work is aimed at preparing for academic classes and at developing knowledge, skills and abilities provided for in the discipline program.  In accordance with the curriculum, the discipline may include Lectures, practical classes and Laboratory work, as well as the execution and defense of a course project (work). Successful study of the discipline requires attending all types of classes, completing teacher assignments and familiarization with basic and additional literature. Depending on the activities provided for in the curriculum and section 4 of this program, the student chooses methodological guidelines for independent work from the ones listed below.  When preparing for lecture classes, students need to:  before the next lecture, it is necessary to review the summary of the material of the previous Lectures. If you have difficulties in perceiving the material, you should refer to the main literary sources. If it was not possible to understand the material again, then contact the lecturer (according to the schedule of his consultations) or the teacher in practical classes.  Practical classes complete the study of the most important topics of the discipline. They serve to consolidate the studied material, develop the skills and abilities of preparing reports, messages, gaining experience in oral public speeches, conducting discussions, argumentation and defending the propositions put forward, as well as to monitor the degree of readiness of students in the discipline being studied by the teacher.  When preparing for a practical lesson, students have the opportunity to use the advice of a teacher.  When preparing for practical classes, students need to:  bring with you the literature recommended by the teacher for a specific lesson;  before the next practical lesson on the recommended literary sources, work out the theoretical material corresponding to the topic of the lesson;  at the beginning of classes, ask the teacher questions about the material that caused difficulties in understanding and mastering it when solving tasks set for independent solution;  during the seminar, give specific, clear answers to the substance of the questions;  at the training session, bring each task to the final solution, demonstrate an understanding of the calculations (analyses, situations), in case of difficulties, contact the teacher.  Students who have missed classes (regardless of the reasons), who do not have a written solution to problems or are not prepared for this practical lesson, are recommended to come to the teacher’s consultation no later than 2 weeks and report on the topic studied in the lesson.  The methodological guidelines necessary for studying and passing the discipline are given as part of the educational program. | | | | |
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| **6.6. METHODOLOGICAL RECOMMENDATIONS FOR THE TRAINING OF PERSONS WITH LIMITED HEALTH OPPORTUNITIES AND THE DISABLED** | | | | |
| The development of the discipline by students with disabilities can be organized both jointly with other students and in separate groups. Special conditions are assumed for students with disabilities to receive education.  The teaching staff gets acquainted with the psychological and physiological characteristics of students with disabilities and persons with disabilities, individual rehabilitation programs for the disabled (if available). If necessary, additional teaching support is provided by tutors, psychologists, social workers, trained assistants.  In accordance with the methodological recommendations of the Ministry of Education and Science of the Russian Federation (approved on April 8, 2014 г. N АК-44/05vn) | | | | |

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| the course is supposed to use socially active and reflective teaching methods, technologies of socio-cultural rehabilitation in order to assist in establishing full-fledged interpersonal relationships with other students, creating a comfortable psychological climate in the student group. Selection and development of educational materials are made taking into account the provision of material in various forms: auditory, visual, using special technical means and information systems.  Mediamaterials should also be used and adapted taking into account the individual characteristics of the training of persons with disabilities.  The development of the discipline by persons with disabilities is carried out using general and special purpose teaching tools (personal and collective use). Material and technical support provides for the adaptation of classrooms to the needs of persons with disabilities.  The form of certification for students with disabilities is established taking into account individual psychophysical characteristics. For students with HIA, an accessible form of assignment of assessment tools is provided, namely:  - in printed or electronic form (for persons with disorders of the musculoskeletal system);  - in printed or electronic form with enlarged font and contrast (for persons with hearing, speech, vision impairments);  - reading the task aloud by the assistant (for visually impaired persons).  Students with disabilities have increased time to prepare answers to control questions. For such students, an accessible form of providing answers to tasks is provided, namely:  - written on paper or a set of answers on a computer (for persons with hearing and speech impairments);  - choosing an answer from possible options using the services of an assistant (for people with musculoskeletal disorders);  - oral interview (for persons with visual impairments, musculoskeletal system).  If necessary, for students with disabilities, the procedure for evaluating learning outcomes can be carried out in several stages. | | |

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| Federal State Budget Educational Institution of Higher Education  «MIREA – Russian Technological University» | | | | | | | | | | | | | | | | | | | | | |
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| **Institute of Physics and Technology** | | | | | | | | | | | | | | | | | | | | | |
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| Working program of the discipline (module) | | | | | | | | | | | | | | | | | | | | | |
| **Communication technologies in the professional domains in a foreign language** | | | | | | | | | | | | | | | | | | | | | |
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|  | Department leading the training | | | | | |  |  | **Department of Foreign Languages (IRTS)** | | | | | | | | | | | | |
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|  | Direction of training | | | | | | |  | **11.04.04 Electronics and nanoelectronics** | | | | | | | | | | | | |
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|  | Profile | | | | | | |  | **Engineering of modern materials for information technology, renewable energy and sensing** | | | | | | | | | | | | |
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|  | Qualification | | | | |  |  |  | **Master** | | | | | | | | | | | | |
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|  | Form of education | | | | |  |  |  | **Full-time** | | | | | | | | | |  |  |  |
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|  | Total labor intensity | | | |  |  |  |  | **3 credits** | | | | | | | | | |  |  |  |
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| **Distribution of discipline hours and forms of intermediate certification by semesters** | | | | | | | | | | | | | | | | | | | | | |
| Semester | | Credits | Distribution of hours | | | | | | | | | | | | | | | Forms of intermediate attestation | | |  |
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| 1 | | 3 | 108 | 0 | | | | 0 | | | 32 | 58 | | 0,25 | | | 17,75 | Test | | |  |
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| The program was made by: |  |  |  |  |
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| *Ph.D. Pedagogical Sciences, Associate Professor, Катахова Н.В. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_* | | | | |
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| Working program of the discipline | | |  |  |
| **Communication technologies in the professional domains in a foreign language** | | | | |
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| it is developed in accordance with FSES HE: | | |  |  |
| Federal State Educational Standard of Higher Education - Magistracy in the Direction of training 11.04.04 Electronics and nanoelectronics (order of the Ministry of Science and Higher Education of the Russian Federation from 22.09.2017. № 959) | | | | |
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| it is based on the curriculum: | | |  |  |
| Direction of training: 11.04.04 Electronics and nanoelectronics  Profile: «Engineering of modern materials for information technology, renewable energy and sensing» | | | | |
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| The working program was approved at the meeting of the department | | | | |
| **Department of Foreign Languages (IRTS)** | | | | |
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| Minutes of meeting from 23.03.2021 № 8  Head of the Department N. Chernova \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ | | | | |

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| **Approval of the WPD for execution in the next academic year** | | | | |
|  |  |  |  |  |
| The working program was revised, discussed and approved for execution in the 2022-2023 academic year at a meeting of the department | | | | |
| **Department of Foreign Languages (IRTS)** | | | | |
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|  | Minutes of meeting from \_\_ \_\_\_\_\_\_\_\_\_\_ 2022. № \_\_  Head of the Department \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ | | | |
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| **Approval of the WPD for execution in the next academic year** | | | | |
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| The working program was revised, discussed and approved for execution in the 2023-2024 academic year at a meeting of the department | | | | |
| **Department of Foreign Languages (IRTS)** | | | | |
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|  | Minutes of meeting from \_\_ \_\_\_\_\_\_\_\_\_\_ 2023. № \_\_  Head of the Department \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ | | | |
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| **Approval of the WPD for execution in the next academic year** | | | | |
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| The working program was revised, discussed and approved for execution in the 2024-2025 academic year at a meeting of the department | | | | |
| **Department of Foreign Languages (IRTS)** | | | | |
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|  | Minutes of meeting from \_\_ \_\_\_\_\_\_\_\_\_\_ 2024. № \_\_  Head of the Department \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ | | | |
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| **Approval of the WPD for execution in the next academic year** | | | | |
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| The working program was revised, discussed and approved for execution in the 2025-2026 academic year at a meeting of the department | | | | |
| **Department of Foreign Languages (IRTS)** | | | | |
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|  | Minutes of meeting from \_\_ \_\_\_\_\_\_\_\_\_\_ 2025. № \_\_  Head of the Department \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ | | | |
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| **1. OBJECTIVES OF MASTERING THE DISCIPLINE (MODULE)** | | | | | |
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| The discipline «Communication technologies in the professional domains in a foreign language» aims to contribute to the formation of students’ competencies, provided by this work program in accordance with the requirements of FSES HE in the direction of training 11.04.04 Electronics and nanoelectronics, taking into account the specifics of the profile – «Engineering of modern materials for information technology, renewable energy and sensing». | | | | | |
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| **2. PLACE OF DISCIPLINE (MODULE) IN THE STRUCTURE OF THE EDUCATIONAL PROGRAM** | | | | | |
|  | Direction of training: |  | 11.04.04 Electronics and nanoelectronics | | |
|  |
|  | Profile: |  | Engineering of modern materials for information technology, renewable energy and sensing | | |
|  |  |  |
|  | Block: |  | Disciplines (modules) | | |
|  |  |  |
|  | Part: |  | Mandatory part | | |
|  |  |  |
|  | Total labor intensity: |  | 3 credits (108 academic hours). | | |
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| **3. THE STUDENT’S COMPETENCIES FORMED AS A RESULT OF MASTERING THE DISCIPLINE (MODULE)** | | | | | |
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| As a result of mastering the practice, the student must master the following competencies: | | | | | |
| **UC-4** - Capable to use modern communication technologies, including the foreign language(s) for academic and professional communication | | | | | |
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| **PLANNED RESULTS OF TRAINING IN THE DISCIPLINE (MODULE), CHARACTERIZING THE FORMATION OF COMPETENCIES** | | | | | |
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| **UC-4 : Capable to use modern communication technologies, including the foreign language(s) for academic and professional communication** | | | | | |
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| **UC-4.1: Capable of prepare the typical business documentation for academic and professional communication** | | | | | |
| **To know:** | | | | | |
| - general rules of business documentation | | | | | |
| **Be able to:** | | | | | |
| - make out different types of business documentation | | | | | |
| **Possess:** | | | | | |
| - master the style of business correspondence in a foreign language | | | | | |
|  |  |  |  |  |  |
| **UC-4.2: Represents the results of their professional activities and participate in discussions in a foreign language** | | | | | |
| **To know:** | | | | | |
| - terminological professional base for professional communication in a foreign language | | | | | |
| **Be able to:** | | | | | |
| - professional vocabulary and basic grammar for oral and written communication in a foreign language | | | | | |
| **Possess:** | | | | | |
| - skills and etiquette of professional communication in a foreign language to participate in professional discussions | | | | | |

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| **AS A RESULT OF STUDYING THE DISCIPLINE (MODULE), THE STUDENT MUST** | | | | | | |
|  |  |  |  |  |  |  |
| **To know:** | | | | | | |
| - terminological professional base for professional communication in a foreign language | | | | | | |
| - general rules of business documentation | | | | | | |
| **Be able to:** | | | | | | |
| - professional vocabulary and basic grammar for oral and written communication in a foreign language | | | | | | |
| - make out different types of business documentation | | | | | | |
| **Possess:** | | | | | | |
| - skills and etiquette of professional communication in a foreign language to participate in professional discussions | | | | | | |
| - master the style of business correspondence in a foreign language | | | | | | |
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| **4. STRUCTURE AND CONTENT OF THE DISCIPLINE (MODULE)** | | | | | | |
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| During the training sessions, the organization ensures the development of students’ teamwork skills, interpersonal communication, decision-making and leadership qualities. | | | | | | |
| **Code** | **Name of sections and topics /type of classes/** | | **Semester** | **Academic Hours** | **Competencies** | |
| **1. Introduction** | | | | | | |
| **1.1** | **Preparation for classroom classes (IWS).** | | 1 | 8 | UC-4.2 | |
| **1.2** | **Performing practical tasks (Pr).** Content and objectives of the course. Requirements for students. Conducting testing in order to determine the level of proficiency in a foreign language. | | 1 | 2 | UC-4.2 | |
| **2. Основной раздел** | | | | | | |
| **2.1** | **Preparation for classroom classes (IWS).** | | 1 | 40 | UC-4.1 | |
| **2.2** | **Performing practical tasks (Pr).** Intercultural communication, Conversations on common topics: work, leisure, invitation, consent, refusal | | 1 | 2 | UC-4.1 | |
| **2.3** | **Performing practical tasks (Pr).** Conversational style, Scientific style, Official business style | | 1 | 2 | UC-4.1 | |
| **2.4** | **Performing practical tasks (Pr).** Conversational style, Scientific style, Official business style (continued) | | 1 | 2 | UC-4.1 | |
| **2.5** | **Performing practical tasks (Pr).** E-mail, telephone conversations, Skype, video conferences, SMS | | 1 | 2 | UC-4.1 | |
| **2.6** | **Performing practical tasks (Pr).** E-mail, telephone conversations, Skype, video conferences, SMS (continued) | | 1 | 2 | UC-4.1 | |
| **2.7** | **Performing practical tasks (Pr).** E-mail, telephone conversations, Skype, video conferences, SMS (continued) | | 1 | 2 | UC-4.1 | |

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| **2.8** | **Performing practical tasks (Pr).** Business (official) correspondence, preparation of summaries, Preparation of reports, memoranda, minutes of meetings | | 1 | 2 | UC-4.1 | |
| **2.9** | **Performing practical tasks (Pr).** Business (official) correspondence, preparation of summaries, Preparation of reports, memoranda, minutes of meetings (continued) | | 1 | 2 | UC-4.1 | |
| **2.10** | **Performing practical tasks (Pr).** Business (official) correspondence, preparation of summaries, Preparation of reports, memoranda, minutes of meetings (continued) | | 1 | 2 | UC-4.1 | |
| **2.11** | **Performing practical tasks (Pr).** Planning and design of articles, Abstracts and abstracts, Reports | | 1 | 2 | UC-4.1 | |
| **2.12** | **Performing practical tasks (Pr).** Planning and design of articles, Abstracts and abstracts, Reports (continued) | | 1 | 2 | UC-4.1 | |
| **2.13** | **Performing practical tasks (Pr).** Planning and design of articles, Abstracts and abstracts, Reports (continued) | | 1 | 2 | UC-4.1 | |
| **2.14** | **Performing practical tasks (Pr).** Planning and design of articles, Abstracts and abstracts, Reports (continued) | | 1 | 2 | UC-4.1 | |
| **2.15** | **Performing practical tasks (Pr).** Planning and design of articles, Abstracts and abstracts, Reports (continued) | | 1 | 2 | UC-4.1 | |
| **2.16** | **Writing a home written work (essay, abstract)** **(IWS).** | | 1 | 10 | UC-4.1 | |
| **2.17** | **Defense of essays** **(Pr).** Presentations, conference reports, project defense | | 1 | 2 | UC-4.1 | |
| **3. Intermediate certification (Test)** | | | | | | |
| **3.1** | **Preparation for the intermediate certification (Test).** | | 1 | 17,75 | UC-4.1, UC-4.2 | |
| **3.2** | **Contact work with the teacher during the intermediate certification (CWC).** | | 1 | 0,25 | UC-4.1, UC-4.2 | |
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| **5. EVALUATION MATERIALS** | | | | | | |
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| **5.1. List of competencies** | | | | | | |
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| List of competencies, the development of which the study of the discipline is aimed at «Communication technologies in the professional domains in a foreign language», with an indication of the results of their formation in the process of mastering the educational program, presented in paragraph 3 of this work program | | | | | | |
| **5.2. Typical control questions and tasks** | | | | | | |
| Example of a task for a section 1:  Entry Test  Use the proper form.  Nouns:  1. Both my (brother-in-law) work in a bank which is situated on the (outskirt/outskirts) of town.  2. Look! Two (aircraft) are flying in the dark sky.  3. My (grandmother) favourite TV series (be) 'Santa Barbara'.  4. When (be) the latest news on TV? - (It, They) (be) at 9 a.m.  5. Two kilometers (be) a long way to go on foot.  6. The police (be) after the escaped prisoners.  7. Oh dear. Measles (be) quite a serious illness.  8. My (sister-in-law) family is not very large.  9. Cambridge University was exclusively for (man) until 1871 when the first (woman) college was opened.  Articles:  10. My uncle was operated yesterday. He is still in ... hospital. I'm going to ... hospital to see him.  11. ... life will be very different in ... future.  12. ... villages-in this part of ... country near ... Thames are very beautiful.  13. ... Nightingales belonged to ... highest social class of ... England.  14. What do you call ... people of ... China? - ... Chinese.  15. ... man must do everything possible to save ... environment and ... life on ... planet of Earth.  16. ... English language was brought onto ... British Isles in ... middle of ... fifth century by ... Angles, Saxons and Jutes who came there from ... North of ... Germany.  17. Near ... British Museum you can see the tall building of ... University of London.  18. ... Statue of Liberty was ... gift of friendship from ... France to ... United States.  Tenses in the Active and Passive Voice. The Sequence of Tenses:  19. I never (read) a story that (interest) me so much as the one I (read) last night.  20. When we (go) to see them last night, they (play) chess, they (say) they (play) since six o'clock.  21. You (go) with us to the Zoo tomorrow if you (be) a good boy.  22. No sooner we (finish) the translation of the text than the bell (ring).  23. Why you (not, make, do) an effort to improve your life? I wish you (make) an effort to change everything.  24. If I (be) you, I (think) twice before accepting his invitation.  25. 1 wish you (discuss) this (serious, seriously) tomorrow. It isn't funny.  26. All the doors and windows (lock) before we went on holiday, but the house (break into) when we (return) home.  27. Our house (surround) by a beautiful garden. The garden (plant) by my grandfather many years ago. | | | | | | |

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| 28. The Cambridge Folk Festival very well (organize), and there are never (any, some) of the serious problems which can (cause) by large crowds.  29. The oldest college in Cambridge University is Peterhouse, which (found) in 1284, and the most recent is Robinson College which (open) in 1977.  30. I'd like to know who Australia (discover) by? - Ask the teacher about it, ...?  31. Dan said that he (call) you (tomorrow). - If he (call) me in the evening, I (be) very busy. I wish he (call) me in the morning.  32. We thought that the parcel (deliver) in time, but the postman (not, come) yet.  33. The furniture (rearrange) today, and the flat (look) very cozy now.  Modal verbs:  34. Let's discuss this over lunch, ...? - OK. We (can, had to, may) discuss this (later, lately).  35. Cambridge (can, must, may) be one of the best-known towns in the world and (may, can, must) (find) on most tourists' lists of places to visit. You (should, have to, might) go there yourself to see this town. I (mustn't, can't, needn’t) do it, I (be) there several times.  36. Everyone (can, should, might) pay taxes to the government. Pronouns and Prepositions:  37. (Some, any, few) beautiful roses (give) (on, to, for). Jane (to, by, at, for) Patrick (by, at, on) (her, hers) birthday.  38. The house was small and there (be) not (many, much, little, a little) rooms in it.  39. (What, how) is Rob like? - He is generous and kind.  40. The secretary just (sign) (this, these, that) letters (of, on, by) behalf (on, for, at, of) the manager.  Adjectives and Adverbs:  41. (Old) she gets, (forgetful) she becomes. (A, the, -) elderly and (at, an, the, -) old (be) often  forgetful.  42.1 think the American version of 'War and Peace' was (lit-tle) interesting than (our, ours).  43. For (far) information, please write to the above address.  44. Now there (be) about 12,000 students in Oxford, and the University and the town live (happy, happily) side by side.  45. Mr. Smith is much (old) than his wife but they are (happy) couple I ever (meet).  Example of a task for a section 2:  Complete the sentences with a preposition.  Example: Many thanks for your prompt reply.  1. I have put some information\_\_\_\_\_\_\_\_\_\_\_\_\_ the post.  2. We believe \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ buying from local suppliers.  3. We are looking \_\_\_\_\_\_\_\_\_\_\_\_\_ a new supplier.  4. I have forwarded your enquiry \_\_\_\_\_\_\_\_\_\_\_\_\_BMES.  5. Where can I buy spare parts \_\_\_\_\_\_\_\_\_\_\_\_\_ our machinery?  6. I am interested \_\_\_\_\_\_\_\_\_\_ your new range of furniture.  7. \_\_\_\_\_\_\_\_\_\_ reference \_\_\_\_\_\_\_\_\_\_ your enquiry, I have attached our latest brochure. |

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| Ex.1. Match the two parts of the sentences used in making enquiries.  1. I’d like to know a. some more information about our products.  2. We are having problems b. to our brochure.  3. We can recommend c. arranging a suitable delivery date.  4. We are looking d. you could send us more information.  5. I’ll send you e. where we can buy spare parts.  6. Please refer f. a supplier in London.  7. We would like to arrange g. on your website.  8. We would be grateful if h. for a new supplier.  9. I couldn’t find the information i a visit  Example of a task for a section 3:  Complete the text with a suitable word from the box. There is one extra word  While On the other hand so nevertheless moreover thus although  Would you like to become a scientist? Many students would answer this question with a definite “no” \_\_\_\_\_\_\_\_\_\_ quite a lot of them dreamed about making scientific breakthroughs in medicine, physics or chemistry in their childhood. Soon do youngsters realize the real scientific work is not that exciting and flashy as it is shown in popular films and comic books. \_\_\_\_\_\_\_\_\_\_, what does it take to become a great scientist?  \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ some inborn gift is thought to be a prerequisite for a great scientist, greatness in science is mainly about hard work and determination, rather than talent and vision. History knows many examples of a great scientific insight being wasted because a scientist wasn't determined enough to continue his work under financial, political or social pressure.  \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ all this hard work might appear pointless if a scientist lacks curiosity and courage to ask questions about the world and try to answer them. \_\_\_\_\_\_\_\_, a great scientist poses unusual questions about the world and is able to apply his determination, skill and infinite energy to find the answer.  \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_, which is more important, a great scientist should never lose sight of his high moral principles and humanistic values so that his discoveries would serve progress and prosperity rather than violence and injustice.  b. Write a similar answer to one of the following questions. Use the word from the box above.  1) What does it take to be a great programmer?  2) What scientist can you call your idol and why?  Example of a task for a section 4.  Task. Speak on the following ways of communication. Comment on each of the way and say which one is the most suitable for you?  1. Letters. 4. Handwritten notes.  2. Face-to-face. 5. Telephone calls. |

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| 3. E-mail  E-mail  Discus or think about these questions  1. About how many emails do you send every day?  2. Who do you send them to?  3. What do you like about emails?  4. What don’t you like about them?  Write a short e-mail (about 30 words) to all staff in the Marketing Department.  Example of a task for a section 5:  Read the instructions and write a letter (60-90 words). Begin it with a salutation and end politely.  You are a senior manager in the Human Resources Department of a big company. Two days ago, you interviewed candidates applied for the position of a sales manager. Write a letter to the successful candidate. Give the name of the position, the starting day, the salary and number of days of annual leave. Add any other information that will be useful.  You may need the following phrases: We are pleased to inform you; you have been successful in your application for the position…; we would like you to start…; your starting salary will be…; you can take … days’ annual leave; a copy of the contract; confirm the acceptance of the offer.  Now the task for you: read this letter of complaint from a customer and write a reply of 50-60 words to your customer.  Dear Sir or Madam!  This morning we received a consignment of printers from you (Order SN206). On unpacking the boxes, we noticed that all the printers were damaged.  Could you please arrange to send a replacement order as soon as possible and arrange to collect the damaged goods? Hopefully, we will not have to pay for this.  Yours faithfully  While replying keep to the layout offered:  - Thanking her for her letter.  - Apologizing for the problem.  - Agreeing to replace the damaged goods today.  - Offering to collect the damaged goods, at no extra cost.  Example of a task for a section 6.  Task. Write a summary and an abstract of the article you’ve read. | | | |
| **5.3. Fund of evaluation Materials** | | | |
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| A complete list of evaluation materials is provided in the Appendix 1. | | | |
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| **6. MATERIAL, TECHNICAL, EDUCATIONAL AND METHODOLOGICAL SUPPORT OF THE DISCIPLINE (MODULE)** | | | |
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| **6.1. MATERIAL AND TECHNICAL SUPPORT OF THE DISCIPLINE (МОДУЛЯ)** | | | |
| **Name of premises** | | **List of main equipment** | |
| Classroom for lectures and seminars, group and individual consultations, ongoing monitoring and intermediate certification | | Multimedia equipment, specialized furniture, sets of demonstration equipment and educational and visual aids that provide thematic illustrations. | |
| Language lab | | Computer equipment with the ability to connect to the Internet | |
| Language lab | | Computer equipment with the ability to connect to the Internet | |
| A room for independent work of students | | Computer equipment with the ability to connect to the Internet and provide access to the electronic information and educational environment of the organization. | |

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| **6.2. LIST OF SOFTWARE** | | | | |
| 1. |  | Microsoft Windows. Contract No. 32009183466 from 02.07.2021. | | |
| 2. |  | Microsoft Office. Contract No. 32009183466 from 02.07.2021. | | |
| 3. |  | Google Chrome. Free software | | |
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| **6.3. RECOMMENDED LITERATURE** | | | | |
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| **6.3.1. Basic literature** | | | | |
| 1. |  | Shevtsova G. V., Moskalec L. E. Anglijskij yazyk dlya tekhnicheskih vuzov:uchebnoe posobie. - M.: FLINTA, 2018. - 392 s. | | |
| 2. |  | Chernova N. I., Katahova N. V. English for Robotics [Electronic resource]:ucheb. posobie dlya bakalavrov, specialistov i magistrantov po napravleniyu podgotovki i spec. "Mekhatronika i robototekhnika". - M.: RTU MIREA, 2019. -– Access mode: http://library.mirea.ru/secret/05062019/2038.iso | | |
| 3. |  | Didyk N. V. Professional English [Electronic resource]:uchebno-metodicheskoe posobie. - M.: RTU MIREA, 2020. – Access mode: https://library.mirea.ru/secret/16022021/2579.iso | | |
| 4. |  | Rybakova M. V. Anglijskij yazyk [Electronic resource]:metod. posobie dlya magistrantov. - M.: MIREA, 2017.- – Access mode: http://library.mirea.ru/secret/12012018/1623.iso | | |
| 5. |  | Udalova N. V., CHugaeva K. M. Simple Compound [Electronic resource]:uchebno- metodicheskoe posobie. - M.: RTU MIREA, 2020.- – Access mode: https://library.mirea.ru/secret/16022021/2582.iso | | |
| 6. |  | Chernova N. I., Katahova N. V. Engineering in english [Electronic resource]:Hrestomatiya. - M.: MIREA, 2018. - – Access mode: http://library.mirea.ru/secret/18062018/1759.iso | | |
| 7. |  | Abajdullina O. S., Karlina N. E. "Can Talk" Part Two [Electronic resource]:uchebno- metod. posobie. - M.: RTU MIREA, 2018. -– Access mode: http://library.mirea.ru/secret/06032019/1970.iso | | |
| 8. |  | Abajdullina O. S., Karlina N. E. "CanTalk" Pat one [Electronic resource]:metod. ukazaniya. - M.: MIREA, 2017. -– Access mode: http://library.mirea.ru/secret/12012018/1621.iso | | |
| 9. |  | Rybakova M. V. Anglijskij yazyk. Testovye zadaniya dlya vneauditornoj samostoyatel'noj raboty [Electronic resource]:Uchebno-metodicheskoe posobie dlya magistrantov tekhnicheskih napravlenij podgotovki. - M.: RTU MIREA, 2020. - – Access mode: https://library.mirea.ru/secret/15032021/2591.iso | | |
| 10. |  | Abajdullina O. S., Ioffe N. E., Kappusheva I. SH. Techno Stories to Be Discussed Part One [Electronic resource]:uchebno-metodicheskoe posobie. - M.: RTU MIREA, 2020. -– Access mode: https://library.mirea.ru/secret/16022021/2578.iso | | |
| 11. |  | Chernova N. I., Katahova N .V. English Grammar Peculiarities Part I [Electronic resource]:uchebno-metodicheskoe posobie po anglijskomu yazyku dlya bakalavrov, magistrantov i aspirantov vsekh napravlenij podgotovki RTU MIREA. - M.: RTU MIREA, 2020. -– Access mode: https://library.mirea.ru/secret/16022021/2556.iso | | |
| 12. |  | Gavrilova E. A. English for Business Communication [Electronic resource]:uchebno- metodicheskoe posobie. - Moscow: RTU MIREA, 2020. - 74 s. – Access mode: https://e.lanbook.com/book/163886 | | |
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| **6.3.2. Additional literature** | | | | |
| 1. |  | Mandzhiev A. A. English essentials for electronics [Electronic resource]:uchebno-metod. posobie. - M.: MIREA, 2016. -– Access mode: http://library.mirea.ru/secret/ab/1387.iso | | |
| 2. |  | Chernova N. I., Katahova N. V., Petrova L. I., i dr. Biznes-anglijskij yazyk. Feel free in your business English [Electronic resource]:uchebnoe posobie dlya magistrantov vsekh napravlenij. - M.: MIREA, 2015. - 68 s. – Access mode: http://library.mirea.ru/secret/rio/1416.pdf | | |

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| 3. |  | Get on well with radioengineering and electronics [Electronic resource]: textbook. - M.: MIREA, 2016. - – Access mode: http://library.mirea.ru/secret/ab/1389.iso | | |
| 4. |  | Chernova N. I., Katakhova N. V., Ulyanova E. F. Guidance to describing graphs, tables and trends. English [Electronic resource]:method. instructions and control and training exercises. - M.: MIREA, 2016. -– Access mode: http://library.mirea.ru/secret/ab/1391.iso | | |
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| **6.4. RECOMMENDED LIST OF MODERN PROFESSIONAL DATABASES AND INFORMATION REFERENCE SYSTEMS** | | | | |
| 1. |  | English Grammar Online https://www.ego4u.com | | |
| 2. |  | MyGrammarLab http://www.MyGrammarLab.com | | |
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| **6.5. METHODICAL INSTRUCTIONS FOR STUDENTS STUDYING THE DISCIPLINE (MODULE)** | | | | |
| The student’s independent work is aimed at preparing for academic classes and at developing knowledge, skills and abilities provided for in the discipline program.  In accordance with the curriculum, the discipline may include Lectures, practical classes and Laboratory work, as well as the execution and defense of a course project (work). Successful study of the discipline requires attending all types of classes, completing teacher assignments and familiarization with basic and additional literature. Depending on the activities provided for in the curriculum and section 4 of this program, the student chooses methodological guidelines for independent work from the ones listed below.  When preparing for lecture classes, students need to:  before the next lecture, it is necessary to review the summary of the material of the previous Lectures. If you have difficulties in perceiving the material, you should refer to the main literary sources. If it was not possible to understand the material again, then contact the lecturer (according to the schedule of his consultations) or the teacher in practical classes.  Practical classes complete the study of the most important topics of the discipline. They serve to consolidate the studied material, develop the skills and abilities of preparing reports, messages, gaining experience in oral public speeches, conducting discussions, argumentation and defending the propositions put forward, as well as to monitor the degree of readiness of students in the discipline being studied by the teacher.  When preparing for a practical lesson, students have the opportunity to use the advice of a teacher.  When preparing for practical classes, students need to:  bring with you the literature recommended by the teacher for a specific lesson;  before the next practical lesson on the recommended literary sources, work out the theoretical material corresponding to the topic of the lesson;  at the beginning of classes, ask the teacher questions about the material that caused difficulties in understanding and mastering it when solving tasks set for independent solution;  during the seminar, give specific, clear answers to the substance of the questions;  at the training session, bring each task to the final solution, demonstrate an understanding of the calculations (analyses, situations), in case of difficulties, contact the teacher.  Students who have missed classes (regardless of the reasons), who do not have a written solution to problems or are not prepared for this practical lesson, are recommended to come to the teacher’s consultation no later than 2 weeks and report on the topic studied in the lesson.  The methodological guidelines necessary for studying and passing the discipline are given as part of the educational program. | | | | |
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| **6.6. METHODOLOGICAL RECOMMENDATIONS FOR THE TRAINING OF PERSONS WITH LIMITED HEALTH OPPORTUNITIES AND THE DISABLED** | | | | |
| The development of the discipline by students with disabilities can be organized both jointly with other students and in separate groups. | | | | |

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| Special conditions are assumed for students with disabilities to receive education.  The teaching staff gets acquainted with the psychological and physiological characteristics of students with disabilities and persons with disabilities, individual rehabilitation programs for the disabled (if available). If necessary, additional teaching support is provided by tutors, psychologists, social workers, trained assistants.  In accordance with the methodological recommendations of the Ministry of Education and Science of the Russian Federation (approved April 8, 2014 N AK-44/05vn), the course is supposed to use socially active and reflective teaching methods, technologies of socio-cultural rehabilitation in order to assist in establishing full-fledged interpersonal relationships with other students, creating a comfortable psychological climate in the student group. Selection and development of educational materials are made taking into account the provision of material in various forms: auditory, visual, using special technical means and information systems.  Mediamaterials should also be used and adapted taking into account the individual characteristics of the training of persons with disabilities.  The development of the discipline by persons with disabilities is carried out using general and special purpose teaching tools (personal and collective use). Material and technical support provides for the adaptation of classrooms to the needs of persons with disabilities.  The form of certification for students with disabilities is established taking into account individual psychophysical characteristics. For students with HIA, an accessible form of assignment of assessment tools is provided, namely:  - in printed or electronic form (for persons with disorders of the musculoskeletal system);  - in printed or electronic form with enlarged font and contrast (for persons with hearing, speech, vision impairments);  - reading the task aloud by the assistant (for visually impaired persons).  Students with disabilities have increased time to prepare answers to control questions. For such students, an accessible form of providing answers to tasks is provided, namely:  - written on paper or a set of answers on a computer (for persons with hearing and speech impairments);  - choosing an answer from possible options using the services of an assistant (for people with musculoskeletal disorders);  - oral interview (for persons with visual impairments, musculoskeletal system).  If necessary, for students with disabilities, the procedure for evaluating learning outcomes can be carried out in several stages. |

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| MINISTRY OF SCIENCE AND HIGHER EDUCATION OF THE RUSSIAN FEDERATION | | | | | | | | | | | | | | | | | | | | | |
| Federal State Budget Educational Institution of Higher Education  «MIREA – Russian Technological University» | | | | | | | | | | | | | | | | | | | | | |
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| **Institute of Physics and Technology** | | | | | | | | | | | | | | | | | | | | | |
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| Working program of the discipline (module) | | | | | | | | | | | | | | | | | | | | | |
| **Computer-based simulations of nanosystems** | | | | | | | | | | | | | | | | | | | | | |
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|  | Department leading the training | | | | | |  |  | **Department of Nanoelectronics** | | | | | | | | | | | | |
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|  | Direction of training | | | | | | |  | **11.04.04 Electronics and nanoelectronics** | | | | | | | | | | | | |
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|  | Profile | | | | | | |  | **Engineering of modern materials for information technology, renewable energy and sensing** | | | | | | | | | | | | |
|  |  |  |  |  |  |  |  |  |
|  | Qualification | | | | |  |  |  | **Master** | | | | | | | | | | | | |
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|  | Form of education | | | | |  |  |  | **Full-time** | | | | | | | | | |  |  |  |
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|  | Total labor intensity | | | |  |  |  |  | **3 credits** | | | | | | | | | |  |  |  |
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| **Distribution of discipline hours and forms of intermediate certification by semesters** | | | | | | | | | | | | | | | | | | | | | |
| Semester | | Credits | Distribution of hours | | | | | | | | | | | | | | | Forms of intermediate attestation | | |  |
| Total | Lectures | | | | Laboratory work | | | Practical classes | Independent work of students | | Contact work during practice and (or) certification | | | Control of training |  |
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| The program was made by: |  |  |  |  |
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| *Ph.D. Physics and Mathematics, Senior lecturer, A. Buryakov \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_* | | | | |
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| Working program of the discipline | | |  |  |
| **Computer-based simulations of nanosystems** | | | | |
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| it is developed in accordance with FSES HE: | | |  |  |
| Federal State Educational Standard of Higher Education - Magistracy in the Direction of training 11.04.04 Electronics and nanoelectronics (order of the Ministry of Science and Higher Education of the Russian Federation from 22.09.2017. № 959) | | | | |
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| it is based on the curriculum: | | |  |  |
| Direction of training: 11.04.04 Electronics and nanoelectronics  Profile: «Engineering of modern materials for information technology, renewable energy and sensing» | | | | |
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| The working program was approved at the meeting of the department | | | | |
| **Department of Nanoelectronics** | | | | |
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| Minutes of meeting from 02.03.2021 № 3  Head of the Department A. Sigov \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ | | | | |

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| **Approval of the WPD for execution in the next academic year** | | | | |
|  |  |  |  |  |
| The working program was revised, discussed and approved for execution in the 2022-2023 academic year at a meeting of the department | | | | |
| **Department of Nanoelectronics** | | | | |
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|  | Minutes of meeting from \_\_ \_\_\_\_\_\_\_\_\_\_ 2022. № \_\_  Head of the Department \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ | | | |
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| **Approval of the WPD for execution in the next academic year** | | | | |
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| The working program was revised, discussed and approved for execution in the 2023-2024 academic year at a meeting of the department | | | | |
| **Department of Nanoelectronics** | | | | |
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|  | Minutes of meeting from \_\_ \_\_\_\_\_\_\_\_\_\_ 2023. № \_\_  Head of the Department \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ | | | |
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| **Approval of the WPD for execution in the next academic year** | | | | |
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| The working program was revised, discussed and approved for execution in the 2024-2025 academic year at a meeting of the department | | | | |
| **Department of Nanoelectronics** | | | | |
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|  | Minutes of meeting from \_\_ \_\_\_\_\_\_\_\_\_\_ 2024. № \_\_  Head of the Department \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ | | | |
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| **Approval of the WPD for execution in the next academic year** | | | | |
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| The working program was revised, discussed and approved for execution in the 2025-2026 academic year at a meeting of the department | | | | |
| **Department of Nanoelectronics** | | | | |
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|  | Minutes of meeting from \_\_ \_\_\_\_\_\_\_\_\_\_ 2025. № \_\_  Head of the Department \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ | | | |
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| **1. OBJECTIVES OF MASTERING THE DISCIPLINE (MODULE)** | | | | | |
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| The discipline «Computer-based simulations of nanosystems» aims to contribute to the formation of students’ competencies, provided by this work program in accordance with the requirements of FSES HE in the direction of training 11.04.04 Electronics and nanoelectronics, taking into account the specifics of the profile – «Engineering of modern materials for information technology, renewable energy and sensing». | | | | | |
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| **2. PLACE OF DISCIPLINE (MODULE) IN THE STRUCTURE OF THE EDUCATIONAL PROGRAM** | | | | | |
|  | Direction of training: |  | 11.04.04 Electronics and nanoelectronics | | |
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|  | Profile: |  | Engineering of modern materials for information technology, renewable energy and sensing | | |
|  |  |  |
|  | Block: |  | Disciplines (modules) | | |
|  |  |  |
|  | Part: |  | Mandatory part | | |
|  |  |  |
|  | Total labor intensity: |  | 3 credits (108 academic hours). | | |
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| **3. THE STUDENT’S COMPETENCIES FORMED AS A RESULT OF MASTERING THE DISCIPLINE (MODULE)** | | | | | |
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| As a result of mastering the practice, the student must master the following competencies: | | | | | |
| **GPC-4** - Capable of developing and applying specialized software and mathematical software for conducting research and solving engineering problems | | | | | |
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| **PLANNED RESULTS OF TRAINING IN THE DISCIPLINE (MODULE), CHARACTERIZING THE FORMATION OF COMPETENCIES** | | | | | |
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| **GPC-4 : Capable of developing and applying specialized software and mathematical software for conducting research and solving engineering problems** | | | | | |
|  |  |  |  |  |  |
| **GPC-4.1: Applies modern computer technologies for the preparation of text and design and technological documentation, taking into account the requirements of regulatory documentation** | | | | | |
| **To know:** | | | | | |
| - The main features of the Maxima and COMSOL Multiphysics analytical computing package are in modeling, analyzing and solving operations research problems and in visualizing source data and resulting solutions, taking into account the requirements of regulatory documentation. | | | | | |
| **Be able to:** | | | | | |
| - use modern automation tools, apply theoretical knowledge in practice using the analytical capabilities of the Maxima and COMSOL package, simulate and solve various tasks of operations research using the Maxima and COMSOL package. | | | | | |
| **Possess:** | | | | | |
| - Modern software tools for the preparation of design and technological documentation, conceptual apparatus and modern computational methods of operations research. | | | | | |
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| **GPC-4.2: Evaluates the optimal software and mathematical support for conducting research** | | | | | |
| **To know:** | | | | | |
| - the basic principles of data representation and the basics of the programming language of the Maxima and COMSOL package; theoretical foundations of operations research; classification of operations research tasks and basic approaches to analyzing and solving problems from various classes. | | | | | |

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| **Be able to:** | | | | | | |
| - visualize and analyze the source data and the results obtained using graphical tools and animation functions of the Maxima and COMSOL package. | | | | | | |
| **Possess:** | | | | | | |
| - software (tools of the Maxima and COMSOL package) used for modeling, analysis and solving operations research problems. | | | | | | |
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| **AS A RESULT OF STUDYING THE DISCIPLINE (MODULE), THE STUDENT MUST** | | | | | | |
|  |  |  |  |  |  |  |
| **To know:** | | | | | | |
| - the basic principles of data representation and the basics of the programming language of the Maxima and COMSOL package; theoretical foundations of operations research; classification of operations research tasks and basic approaches to analyzing and solving problems from various classes. | | | | | | |
| - The main features of the Maxima and COMSOL Multiphysics analytical computing package are in modeling, analyzing and solving operations research problems and in visualizing source data and resulting solutions, taking into account the requirements of regulatory documentation. | | | | | | |
| **Be able to:** | | | | | | |
| - visualize and analyze the source data and the results obtained using graphical tools and animation functions of the Maxima and COMSOL package. | | | | | | |
| - use modern automation tools, apply theoretical knowledge in practice using the analytical capabilities of the Maxima and COMSOL package, simulate and solve various tasks of operations research using the Maxima and COMSOL package. | | | | | | |
| **Possess:** | | | | | | |
| - software (tools of the Maxima and COMSOL package) used for modeling, analysis and solving operations research problems. | | | | | | |
| - Modern software tools for the preparation of design and technological documentation, conceptual apparatus and modern computational methods of operations research. | | | | | | |
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| **4. STRUCTURE AND CONTENT OF THE DISCIPLINE (MODULE)** | | | | | | |
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| During the training sessions, the organization ensures the development of students’ teamwork skills, interpersonal communication, decision-making and leadership qualities. | | | | | | |
| **Code** | **Name of sections and topics /type of classes/** | | **Semester** | **Academic Hours** | **Competencies** | |
| **1. Introduction to Computer Modeling** | | | | | | |
| **1.1** | **Lecture** **1.** **Introduction to Maxima and COMSOL Multiphysics.** **(Lec).** Getting started in Maxima and COMSOL Multiphysics. Physical interfaces. The working window of the program. The main stages of work in Maxima and COMSOL Multiphysics. | | 1 | 2 | GPC-4.1 | |
| **1.2** | **Lecture** **2.** **Introduction to COMSOL Multiphysics.** **(Lec).** Getting Started with Maxima and COMSOL Multiphysics. | | 1 | 2 | GPC-4.1 | |
| **1.3** | **Lecture** **3.** **The basic principles of constructing calculations and lists in Maxima. (Lec).** Using previous results. Definition of variables. Values for symbols. | | 1 | 2 | GPC-4.1 | |

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| **1.4** | **Lecture** **4.** **Functions and programs. Functional operations. Elementary calculations.** **(Lec).** Definition of functions. Functions as procedures. Using options. Recurring operations. | 1 | 2 | GPC-4.1 |
| **1.5** | **Performing practical tasks (Pr).** PR 1. Programming and mathematical calculation in Maxima. | 1 | 2 | GPC-4.1 |
| **1.6** | **Performing practical tasks (Pr).** PR 2. Learning the structure and basics of working in the Maxima package. | 1 | 2 | GPC-4.1 |
| **1.7** | **Performing practical tasks (Pr).** PR 3. Basics of working in the COMSOL Multiphysics physical process modeling software package, getting started, physical interfaces | 1 | 2 | GPC-4.1 |
| **1.8** | **Performing practical tasks (Pr).** PR 4. The working window of the program. The main stages of work in Maxima and COMSOL Multiphysics. | 1 | 2 | GPC-4.1 |
| **1.9** | **Performing practical tasks (Pr).** PR 5. Functions and programs. Functional operations. Elementary calculations. Maxima. | 1 | 2 | GPC-4.1 |
| **1.10** | **Performing practical tasks (Pr).** PR 6. Writing code in Maxima for the Snellius law taking into account the dynamic interactive model | 1 | 2 | GPC-4.1 |
| **1.11** | **Performing practical tasks (Pr).** PR 7. Building lists by means of functions. | 1 | 2 | GPC-4.1 |
| **1.12** | **Performing practical tasks (Pr).** PR 8. Calculation of the laser beam diameter using embedded data, spline function. | 1 | 2 | GPC-4.1 |
| **1.13** | **Performing practical tasks (Pr).** PR 9. Calculation of the diameter of the laser beam from real experimental data obtained by overlapping the laser beam. | 1 | 2 | GPC-4.1 |
| **1.14** | **Performing practical tasks (Pr).** PR 10. Import data to Maxima. | 1 | 2 | GPC-4.1 |
| **1.15** | **Performing practical tasks (Pr).** PR 11. Creating tables of values. | 1 | 2 | GPC-4.1 |
| **1.16** | **Performing practical tasks (Pr).** PR 12. Four types of brackets in Maxima. | 1 | 2 | GPC-4.1 |
| **1.17** | **Homework (IWS).** SRS 1. Literature analysis, Homework | 1 | 7 | GPC-4.1, GPC -4.2 |
| **1.18** | **Preparation for classroom classes (IWS).** Preparation for Lecture and practical classes | 1 | 6 | GPC-4.1, GPC -4.2 |

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| **2. Modeling of physical processes** | | | | |
| **2.1** | **Lecture** **5.** **Visualization and graphics.** **(Lec).** Spline functions. Creating graphics using spline primitives. Plotting graphs. Graphs of functions with one variable. Graphs of functions with two variables. Graphs of parametric functions. Graphical display of data. Creating graphs with two vertical scales. Creating 3D graphics. 3D data graphs. Graphical display of NDSolve results. Graphical tools for checking the correctness of the selection of the model by points. Vector field graph. | 1 | 2 | GPC-4.2 |
| **2.2** | **Lecture** **6.** **Working with data (Lec).** Using embedded data. Spline functions. Creating graphics using spline primitives. | 1 | 2 | GPC-4.2 |
| **2.3** | **Lecture** **7.** **Basics of automation and dynamic interactivity in Maxima.** **(Lec).** Creating an animation. Creating program code in Maxima for an interactive model describing physical laws. Creating user interfaces. | 1 | 2 | GPC-4.2 |
| **2.4** | **Lecture** **8.** **Modeling of physical processes in various computer packages. (Lec).** Modeling of electromagnetic radiation processes in nanostructures using the Maxima and COMSOL Multiphysics software package, comparison of simulation results, estimation of calculation errors performed in different packages. | 1 | 2 | GPC-4.2 |
| **2.5** | **Performing practical tasks (Pr).** PR 13. A list as a set of objects. | 1 | 2 | GPC-4.1 |
| **2.6** | **Performing practical tasks (Pr).** PR 14. Vectors and matrices. Extracting parts of lists. | 1 | 2 | GPC-4.1 |
| **2.7** | **Performing practical tasks (Pr).** Pr 15. Creating a graph of the diameter of a laser beam using spline primitives | 1 | 2 | GPC-4.2 |
| **2.8** | **Performing practical tasks (Pr).** PR 16. Modeling the distribution of electromagnetic radiation. | 1 | 2 | GPC-4.2 |
| **2.9** | **Performing practical tasks (Pr).** PR 17. Modeling of electromagnetic radiation distribution in layered nanostructures. | 1 | 2 | GPC-4.2 |
| **2.10** | **Performing practical tasks (Pr).** PR 18. Modeling of electromagnetic radiation distribution in layered nanostructures taking into account Fresnel formulas in the Maxima software package. | 1 | 2 | GPC-4.2 |
| **2.11** | **Performing practical tasks (Pr).** PR 19. Modeling of electromagnetic radiation distribution in layered nanostructures by the finite element method in COMSOL Multiphysics. | 1 | 2 | GPC-4.2 |

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| **2.12** | **Performing practical tasks (Pr).** PR 20. Comparison of simulation results obtained by different methods, error estimation. | | | 1 | 2 | GPC-4.2 | |
| **2.13** | **Performing practical tasks (Pr).** PR 21. Creating an animation. | | | 1 | 2 | GPC-4.2 | |
| **2.14** | **Performing practical tasks (Pr).** PR 22. Creating program code in Maxima for an interactive model describing physical laws. | | | 1 | 2 | GPC-4.2 | |
| **2.15** | **Performing practical tasks (Pr).** PR 23. Creating user interfaces. | | | 1 | 2 | GPC-4.2 | |
| **2.16** | **Performing practical tasks (Pr).** PR 24. Using embedded data. Spline functions. Creating graphics using spline primitives. | | | 1 | 2 | GPC-4.2 | |
| **2.17** | **Homework (IWS).** SRS 2. Literature analysis, Homework | | | 1 | 7 | GPC-4.1, GPC -4.2 | |
| **2.18** | **Preparation for classroom classes (IWS).** Preparation for lectures and practical classes | | | 1 | 6 | GPC-4.1, GPC -4.2 | |
| **3. Intermediate certification (Test)** | | | | | | | |
| **3.1** | **Preparation for the intermediate certification (Test).** | | | 1 | 17,75 | GPC-4.1, GPC -4.2 | |
| **3.2** | **Contact work with the teacher during the intermediate certification (CWC).** | | | 1 | 0,25 | GPC-4.1, GPC -4.2 | |
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| **5. EVALUATION MATERIALS** | | | | | | | |
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| **5.1. List of competencies** | | | | | | | |
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| List of competencies, the development of which the study of the discipline is aimed at «Computer-based simulations of nanosystems», with an indication of the results of their formation in the process of mastering the educational program, presented in paragraph 3 of this work program | | | | | | | |
| **5.2. Typical control questions and tasks** | | | | | | | |
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| 1. Interface features (concepts of kernel and workspace (notebook) of the package. Package reference system. Embedded modules (add-ons). Maxima interface and COMSOL Multiphysics, the main blocks.  2. Creating a new project in the studied modeling packages;  3. Basics of the programming language of the Maxima package. The concept of an object. Types of objects. A list as a form of internal representation of objects. | | | | | | | |
| **5.3. Fund of evaluation Materials** | | | | | | | |
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| A complete list of evaluation materials is provided in the Appendix 1. | | | | | | | |
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| **6. MATERIAL, TECHNICAL, EDUCATIONAL AND METHODOLOGICAL SUPPORT OF THE DISCIPLINE (MODULE)** | | | | | | | |
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| **6.1. MATERIAL AND TECHNICAL SUPPORT OF THE DISCIPLINE (МОДУЛЯ)** | | | | | | | |
| **Name of premises** | | | **List of main equipment** | | | | |
| Specialized Educational and Scientific Laboratory for Modeling and Designing Elements of Microsystem Technology | | | Computer equipment with the ability to connect to the Internet | | | | |

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| Classroom for lectures and seminars, group and individual consultations, ongoing monitoring and intermediate certification | | | | Multimedia equipment, specialized furniture, sets of demonstration equipment and educational and visual aids that provide thematic illustrations. | |
| A room for independent work of students | | | | Computer equipment with the ability to connect to the Internet and provide access to the electronic information and educational environment of the organization. | |
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| **6.2. LIST OF SOFTWARE** | | | | | |
| 1. |  | Microsoft Windows. Contract No. 32009183466 from 02.07.2021. | | | |
| 2. |  | Microsoft Office. Contract No. 32009183466 from 02.07.2021. | | | |
| 3. |  | COMSOL Multiphysics. Sublicense contract No. 31705027784 from 12.05.2017. | | | |
| 4. |  | MAXIMA Computer Algebra Package. Free software (License GNU GPL) | | | |
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| **6.3. RECOMMENDED LITERATURE** | | | | | |
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| **6.3.1. Basic literature** | | | | | |
| 1. |  | Kovalenko A. V., Uzdenova A. M., Urtenov M. H., Nikonenko V. V. Matematicheskoe modelirovanie fiziko-himicheskih processov v srede COMSOL Multiphysics 5.2 [Electronic resource]:. - Sankt-Peterburg: Lan', 2021. - 228 s. – Access mode: https://e.lanbook.com/book/167416 | | | |
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| **6.3.2. Additional literature** | | | | | |
| 1. |  | Esayan A. R., Dobrovol'skij N. M., CHubarikov V. N., YAkushin A. V. Programmirovanie v Maxima [Electronic resource]:. - Tula: Izdatel'stvo TGPU im.L.N.Tolstogo, 2012. - 352 – Access mode: https://lib.rucont.ru/efd/206400 | | | |
| 2. |  | Chernushkin V. V., Ovsyannikov V. D. Modelirovanie zadach kvantovoj mekhaniki v srede maxima [Electronic resource]:. - Voronezh: VGU, 2016. - 78 s. – Access mode: https://e.lanbook.com/book/165344 | | | |
| 3. |  | Bezruchkina, Sadchikov, Tkacheva Simvol'nye vychisleniya v sisteme komp'yuternoj matematiki Maxima [Electronic resource]. - [n/d]: Voronezh, 2015. - 63 – Access mode: https://lib.rucont.ru/efd/590437 | | | |
| 4. |  | Pevtsov E. F. AVTOMATIZACIYA FIZICHESKOGO EKSPERIMENTA [Electronic resource]:. - M.: MIREA, 2013. - 42 s. – Access mode: http://library.mirea.ru/secret/mr\_145.pdf | | | |
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| **6.4. RECOMMENDED LIST OF MODERN PROFESSIONAL DATABASES AND INFORMATION REFERENCE SYSTEMS** | | | | | |
| 1. |  | Website of the PTI Department of Nanoelectronics https://fks.mirea.ru | | | |
| 2. |  | iXBT — online publication about computer technology  https://www.ixbt.com | | | |
| 3. |  | An international resource for the search and exchange of scientific publications  https://www.researchgate.net | | | |
| 4. |  | Wolfram Mathworld: The Web's Most Extensive Mathematics Resourse http://www.mathworld.wolfram.com | | | |
| 5. |  | Wolfram: computing and knowledge, hand to hand http://www.wolfram.com | | | |
| 6. |  | Stephen Wolfram: Official Website http://www.stephenwolfram.com | | | |
| 7. |  | COMSOL Multiphysics® Software for multiphysical modeling https://www.COMSOL.ru | | | |
| 8. |  | Database Web of Science  http://www.webofknowledge.com | | | |

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| 9. |  | News and analytical portal "Vremya elektroniki "  http://www.russianelectronics.ru | | |
| 10. |  | Journal «Nano- and Microsystem Technology»  http://www.microsystems.ru | | |
| 11. |  | National Research Center «Kurchatov Institute»  http://www.kcsni.nrcki.ru | | |
| 12. |  | Elektronika NTB - scientific and technical journal  http://www.electronics.ru | | |
| 13. |  | Russian Technological Journal  https://www.rtj.mirea.ru | | |
| 14. |  | Scientific Electronic Library http://www.elibrary.ru | | |
| 15. |  | Information portal «Popular nanotechnologies» http://www.popnano.ru | | |
| 16. |  | Electronic fund of legal and regulatory technical documentation Tekhnoexpert http://www.docs.cntd.ru | | |
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| **6.5. METHODICAL INSTRUCTIONS FOR STUDENTS STUDYING THE DISCIPLINE (MODULE)** | | | | |
| The student’s independent work is aimed at preparing for academic classes and at developing knowledge, skills and abilities provided for in the discipline program.  In accordance with the curriculum, the discipline may include Lectures, practical classes and Laboratory work, as well as the execution and defense of a course project (work). Successful study of the discipline requires attending all types of classes, completing teacher assignments and familiarization with basic and additional literature. Depending on the activities provided for in the curriculum and section 4 of this program, the student chooses methodological guidelines for independent work from the ones listed below.  When preparing for lecture classes, students need to:  before the next lecture, it is necessary to review the summary of the material of the previous Lectures. If you have difficulties in perceiving the material, you should refer to the main literary sources. If it was not possible to understand the material again, then contact the lecturer (according to the schedule of his consultations) or the teacher in practical classes.  Practical classes complete the study of the most important topics of the discipline. They serve to consolidate the studied material, develop the skills and abilities of preparing reports, messages, gaining experience in oral public speeches, conducting discussions, argumentation and defending the propositions put forward, as well as to monitor the degree of readiness of students in the discipline being studied by the teacher.  When preparing for a practical lesson, students have the opportunity to use the advice of a teacher.  When preparing for practical classes, students need to:  bring with you the literature recommended by the teacher for a specific lesson;  before the next practical lesson on the recommended literary sources, work out the theoretical material corresponding to the topic of the lesson;  at the beginning of classes, ask the teacher questions about the material that caused difficulties in understanding and mastering it when solving tasks set for independent solution;  during the seminar, give specific, clear answers to the substance of the questions;  at the training session, bring each task to the final solution, demonstrate an understanding of the calculations (analyses, situations), in case of difficulties, contact the teacher.  Students who have missed classes (regardless of the reasons), who do not have a written solution to problems or are not prepared for this practical lesson, are recommended to come to the teacher’s consultation no later than 2 weeks and report on the topic studied in the lesson. | | | | |

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| The methodological guidelines necessary for studying and passing the discipline are given as part of the educational program. | | |
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| **6.6. METHODOLOGICAL RECOMMENDATIONS FOR THE TRAINING OF PERSONS WITH LIMITED HEALTH OPPORTUNITIES AND THE DISABLED** | | |
| The development of the discipline by students with disabilities can be organized both jointly with other students and in separate groups. Special conditions are assumed for students with disabilities to receive education.  The teaching staff gets acquainted with the psychological and physiological characteristics of students with disabilities and persons with disabilities, individual rehabilitation programs for the disabled (if available). If necessary, additional teaching support is provided by tutors, psychologists, social workers, trained assistants.  In accordance with the methodological recommendations of the Ministry of Education and Science of the Russian Federation (approved April 8, 2014 N AK-44/05vn), the course is supposed to use socially active and reflective teaching methods, technologies of socio-cultural rehabilitation in order to assist in establishing full-fledged interpersonal relationships with other students, creating a comfortable psychological climate in the student group. Selection and development of educational materials are made taking into account the provision of material in various forms: auditory, visual, using special technical means and information systems.  Mediamaterials should also be used and adapted taking into account the individual characteristics of the training of persons with disabilities.  The development of the discipline by persons with disabilities is carried out using general and special purpose teaching tools (personal and collective use). Material and technical support provides for the adaptation of classrooms to the needs of persons with disabilities.  The form of certification for students with disabilities is established taking into account individual psychophysical characteristics. For students with HIA, an accessible form of assignment of assessment tools is provided, namely:  - in printed or electronic form (for persons with disorders of the musculoskeletal system);  - in printed or electronic form with enlarged font and contrast (for persons with hearing, speech, vision impairments);  - reading the task aloud by the assistant (for visually impaired persons).  Students with disabilities have increased time to prepare answers to control questions. For such students, an accessible form of providing answers to tasks is provided, namely:  - written on paper or a set of answers on a computer (for persons with hearing and speech impairments);  - choosing an answer from possible options using the services of an assistant (for people with musculoskeletal disorders);  - oral interview (for persons with visual impairments, musculoskeletal system).  If necessary, for students with disabilities, the procedure for evaluating learning outcomes can be carried out in several stages. | | |

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| Federal State Budget Educational Institution of Higher Education  «MIREA – Russian Technological University» | | | | | | | | | | | | | | | | | | | | | |
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| Working program of the discipline (module) | | | | | | | | | | | | | | | | | | | | | |
| **Materials for biomedical applications** | | | | | | | | | | | | | | | | | | | | | |
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|  | Department leading the training | | | | | |  |  | **Department of Nanoelectronics** | | | | | | | | | | | | |
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|  | Direction of training | | | | | | |  | **11.04.04 Electronics and nanoelectronics** | | | | | | | | | | | | |
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|  | Profile | | | | | | |  | **Engineering of modern materials for information technology, renewable energy and sensing** | | | | | | | | | | | | |
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|  | Qualification | | | | |  |  |  | **Master** | | | | | | | | | | | | |
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|  | Form of education | | | | |  |  |  | **Full-time** | | | | | | | | | |  |  |  |
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| **Distribution of discipline hours and forms of intermediate certification by semesters** | | | | | | | | | | | | | | | | | | | | | |
| Semester | | Credits | Distribution of hours | | | | | | | | | | | | | | | Forms of intermediate attestation | | |  |
| Total | Lectures | | | | Laboratory work | | | Practical classes | Independent work of students | | Contact work during practice and (or) certification | | | Control of training |  |
| 2 | | 5 | 180 | 16 | | | | 0 | | | 48 | 80 | | 2,35 | | | 33,65 | Exam | | |  |
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| The program was made by: |  |  |  |  |
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| *Senior lecturer, T. Rassadina \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_* | | | | |
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| Working program of the discipline | | |  |  |
| **Materials for biomedical applications** | | | | |
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| it is developed in accordance with FSES HE: | | |  |  |
| Federal State Educational Standard of Higher Education - Magistracy in the Direction of training 11.04.04 Electronics and nanoelectronics (order of the Ministry of Science and Higher Education of the Russian Federation from 22.09.2017. № 959) | | | | |
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| it is based on the curriculum: | | |  |  |
| Direction of training: 11.04.04 Electronics and nanoelectronics  Profile: «Engineering of modern materials for information technology, renewable energy and sensing» | | | | |
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| The working program was approved at the meeting of the department | | | | |
| **Department of Nanoelectronics** | | | | |
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| Minutes of meeting from 02.03.2021 № 3  Head of the Department A. Sigov \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ | | | | |

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| **Approval of the WPD for execution in the next academic year** | | | | |
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| The working program was revised, discussed and approved for execution in the 2022-2023 academic year at a meeting of the department | | | | |
| **Department of Nanoelectronics** | | | | |
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|  | Minutes of meeting from \_\_ \_\_\_\_\_\_\_\_\_\_ 2022. № \_\_  Head of the Department \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ | | | |
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| **Approval of the WPD for execution in the next academic year** | | | | |
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| The working program was revised, discussed and approved for execution in the 2023-2024 academic year at a meeting of the department | | | | |
| **Department of Nanoelectronics** | | | | |
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|  | Minutes of meeting from \_\_ \_\_\_\_\_\_\_\_\_\_ 2023. № \_\_  Head of the Department \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ | | | |
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| **Approval of the WPD for execution in the next academic year** | | | | |
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| The working program was revised, discussed and approved for execution in the 2024-2025 academic year at a meeting of the department | | | | |
| **Department of Nanoelectronics** | | | | |
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|  | Minutes of meeting from \_\_ \_\_\_\_\_\_\_\_\_\_ 2024. № \_\_  Head of the Department \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ | | | |
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| **Approval of the WPD for execution in the next academic year** | | | | |
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| The working program was revised, discussed and approved for execution in the 2025-2026 academic year at a meeting of the department | | | | |
| **Department of Nanoelectronics** | | | | |
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|  | Minutes of meeting from \_\_ \_\_\_\_\_\_\_\_\_\_ 2025. № \_\_  Head of the Department \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ | | | |
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| **1. OBJECTIVES OF MASTERING THE DISCIPLINE (MODULE)** | | | | | |
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| The discipline «Materials for biomedical applications» aims to contribute to the formation of students’ competencies, provided by this work program in accordance with the requirements of FSES HE in the direction of training 11.04.04 Electronics and nanoelectronics, taking into account the specifics of the profile – «Engineering of modern materials for information technology, renewable energy and sensing». | | | | | |
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| **2. PLACE OF DISCIPLINE (MODULE) IN THE STRUCTURE OF THE EDUCATIONAL PROGRAM** | | | | | |
|  | Direction of training: |  | 11.04.04 Electronics and nanoelectronics | | |
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|  | Profile: |  | Engineering of modern materials for information technology, renewable energy and sensing | | |
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|  | Block: |  | Disciplines (modules) | | |
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|  | Part: |  | Part of the curriculum formed by the participants of educational | | |
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|  | Total labor intensity: |  | 5 credits (180 academic hours). | | |
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| **3. THE STUDENT’S COMPETENCIES FORMED AS A RESULT OF MASTERING THE DISCIPLINE (MODULE)** | | | | | |
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| As a result of mastering the practice, the student must master the following competencies: | | | | | |
| **PC-1** - Capable to apply in-depth knowledge of the structure, physical, physicochemical properties, the purpose of nanomaterials and nanostructures, and methods of measuring their parameters | | | | | |
| **PC-2** - Capable to participate in the development and implementation of modern technological processes, the master of new equipment, technological equipment, the necessary modes of production of micro- and nanoelectronics | | | | | |
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| **PLANNED RESULTS OF TRAINING IN THE DISCIPLINE (MODULE), CHARACTERIZING THE FORMATION OF COMPETENCIES** | | | | | |
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| **PC-1 : Capable to apply in-depth knowledge of the structure, physical, physicochemical properties, the purpose of nanomaterials and nanostructures, and methods of measuring their parameters** | | | | | |
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| **PC-1.2: Analyzes the technological problem at the given norms of technological production, highlighting its basic components and searches for reliable information to solve it for various types of queries** | | | | | |
| **To know:** | | | | | |
| - norms of technological production of materials | | | | | |
| **Be able to:** | | | | | |
| - analyze technological problems and identify the basic components | | | | | |
| **Possess:** | | | | | |
| - methods of searching for reliable information | | | | | |
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| **PC-2 : Capable to participate in the development and implementation of modern technological processes, the master of new equipment, technological equipment, the necessary modes of production of micro- and nanoelectronics** | | | | | |

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| **PC-2.1: Participates in the development and implementation of modern technological processes, the development of new equipment, technological equipment, the necessary modes of production of micro- and nanoelectronics products** | | | | | | |
| **To know:** | | | | | | |
| - the main technological processes of manufacturing materials | | | | | | |
| **Be able to:** | | | | | | |
| - to analyze technical requirements and results of scientific research of materials | | | | | | |
| **Possess:** | | | | | | |
| - Skills in choosing production modes | | | | | | |
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| **PC-2.2: Evaluates optimal processes and modes in the development of electronics products** | | | | | | |
| **To know:** | | | | | | |
| - technological bases of processes and methods of manufacturing and processing of structural materials | | | | | | |
| **Be able to:** | | | | | | |
| - choose alloys and processing modes that ensure the formation of the necessary structure and a set of physical and mechanical properties for various operating conditions | | | | | | |
| **Possess:** | | | | | | |
| - basic knowledge of the physicochemical bases of production, properties and ways of using various materials | | | | | | |
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| **AS A RESULT OF STUDYING THE DISCIPLINE (MODULE), THE STUDENT MUST** | | | | | | |
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| **To know:** | | | | | | |
| - technological bases of processes and methods of manufacturing and processing of structural materials | | | | | | |
| - the main technological processes of manufacturing materials | | | | | | |
| - norms of technological production of materials | | | | | | |
| **Be able to:** | | | | | | |
| - choose alloys and processing modes that ensure the formation of the necessary structure and a set of physical and mechanical properties for various operating conditions | | | | | | |
| - to analyze technical requirements and results of scientific research of materials | | | | | | |
| - analyze technological problems and identify the basic components | | | | | | |
| **Possess:** | | | | | | |
| - basic knowledge of the physicochemical bases of production, properties and ways of using various materials | | | | | | |
| - Skills in choosing production modes | | | | | | |
| - methods of searching for reliable information | | | | | | |
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| **4. STRUCTURE AND CONTENT OF THE DISCIPLINE (MODULE)** | | | | | | |
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| During the training sessions, the organization ensures the development of students’ teamwork skills, interpersonal communication, decision-making and leadership qualities. | | | | | | |
| **Code** | **Name of sections and topics /type of classes/** | | **Semester** | **Academic Hours** | **Competencies** | |
| **1. Structural materials** | | | | | | |

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| **1.1** | **Lecture** **1.** **Classification of structural materials. Introduction (Lec).** Introduction. Structural materials and their properties. Requirements for structural materials. Material selection. Classification of structural materials: by field of application, by the nature of materials, by working conditions, by strength criteria, by technological design. The main types of structural materials. | 2 | 2 | PC-2.1 |
| **1.2** | **Lecture** **2.** **The structure of metallic materials.** **(Lec).** Crystal structure and methods of crystal description; crystal anisotropy, its significance. Defects of the crystal structure and their role in the formation of the structure and properties of materials. | 2 | 2 | PC-2.1 |
| **1.3** | **Lecture** **3.** **Fundamentals of alloy theory and phase equilibrium diagrams (Lec).** The equilibrium state. Component, phase, structural component. The main types of alloys are: solid solution, chemical compound, heterogeneous structure. Graphical representation of the alloy state, phase rule, segment rule, the main types of phase equilibrium diagrams. | 2 | 2 | PC-1.2 |
| **1.4** | **Lecture** **4. Classification of steels (Lec).** Classification of steels: by purpose - structural; instrumental; steels with special physical properties; by chemical composition - carbonaceous; alloyed; by quality - ordinary quality; high-quality; high-quality. Marking of steels. | 2 | 2 | PC-1.2, PC- 2.1, PC-2.2 |
| **1.5** | **Lecture** **5.** **Structural steels (Lec).** Requirements for structural steels. Diagram of the "iron-carbon" state. Methods of heat treatment of steels. The influence of carbon, permanent impurities and alloying elements on the properties of steel. Current trends in the field of alloying. | 2 | 2 | PC-1.2, PC- 2.1, PC-2.2 |
| **1.6** | **Lecture** **6. Non-ferrous metals and alloys based on them** **(Lec).** Aluminum and its alloys. Magnesium-based alloys. Copper and its alloys. Titanium and its alloys. Structural titanium alloys, their properties and applications. | 2 | 2 | PC-1.2, PC- 2.1, PC-2.2 |
| **1.7** | **Lecture** **7.** **Materials processing technologies (Lec).** Technological processes of metal processing. | 2 | 2 | PC-1.2, PC- 2.1, PC-2.2 |
| **1.8** | **Lecture** **8.** **Technologies of non-metallic materials (Lec).** Technology of ceramics manufacturing. Technology of applying ceramic coatings. Compaction of powder materials. Constructions of metal-ceramic assemblies. | 2 | 2 | PC-1.2, PC- 2.1, PC-2.2 |

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| **1.9** | **Performing practical tasks (Pr).** The choice of material for the manufacture of products part 1 | 2 | 2 | PC-2.1, PC-2.2 |
| **1.10** | **Holding a round table (Pr).** The choice of material for the manufacture of products part 2 | 2 | 2 | PC-2.1, PC- 2.2, PC-1.2 |
| **1.11** | **Performing practical tasks (Pr).** Technologies for obtaining materials part 1 | 2 | 2 | PC-2.1, PC-2.2 |
| **1.12** | **Performing practical tasks (Pr).** Technologies for obtaining materials part 2 | 2 | 2 | PC-2.1, PC-2.2 |
| **1.13** | **Performing practical tasks (Pr).** Decoding of structural steel grades | 2 | 2 | PC-2.2 |
| **1.14** | **Performing practical tasks (Pr).** Plasticity and resistance to deformation of the material during cold and hot deformation of workpieces | 2 | 2 | PC-2.1, PC-2.2 |
| **1.15** | **Performing practical tasks (Pr).** Technologies of joining metal with ceramics. | 2 | 2 | PC-2.1, PC-2.2 |
| **1.16** | **Solution of the control work (Pr).** Control work | 2 | 2 | PC-1.2, PC- 2.1, PC-2.2 |
| **1.17** | **Oral interview (Pr).** Questions about the lecture 1 | 2 | 2 | PC-1.2, PC- 2.1, PC-2.2 |
| **1.18** | **Oral interview (Pr).** Questions about the lecture 2 | 2 | 2 | PC-1.2, PC- 2.1, PC-2.2 |
| **1.19** | **Oral interview (Pr).** Questions about the lecture 3 | 2 | 2 | PC-1.2, PC- 2.1, PC-2.2 |
| **1.20** | **Oral interview (Pr).** Questions about the lecture 4 | 2 | 2 | PC-1.2, PC- 2.1, PC-2.2 |
| **1.21** | **Oral interview (Pr).** Questions about the lecture 5 | 2 | 2 | PC-1.2, PC- 2.1, PC-2.2 |
| **1.22** | **Oral interview (Pr).** Questions about the lecture 6 | 2 | 2 | PC-1.2, PC- 2.1, PC-2.2 |
| **1.23** | **Oral interview (Pr).** Questions about the lecture 7 | 2 | 2 | PC-1.2, PC- 2.1, PC-2.2 |
| **1.24** | **Oral interview (Pr).** Questions about the lecture 8 | 2 | 2 | PC-1.2, PC- 2.1, PC-2.2 |
| **1.25** | **Defense of essays** **(Pr).** Defense of essays on the subject of structural materials. | 2 | 2 | PC-1.2, PC-2.2 |
| **1.26** | **Defense of essays** **(Pr).** Defense of essays on the subject of structural materials. | 2 | 2 | PC-1.2, PC-2.2 |
| **1.27** | **Defense of essays** **(Pr).** Defense of essays on the subject of structural materials. | 2 | 2 | PC-1.2, PC-2.2 |
| **1.28** | **Defense of essays** **(Pr).** Defense of essays on the subject of structural materials. | 2 | 2 | PC-1.2, PC-2.2 |
| **1.29** | **Defense of essays** **(Pr).** Defense of essays on the subject of structural materials. | 2 | 2 | PC-1.2, PC-2.2 |
| **1.30** | **Defense of essays** **(Pr).** Defense of essays on the subject of structural materials. | 2 | 2 | PC-1.2, PC-2.2 |
| **1.31** | **Defense of essays** **(Pr).** Defense of essays on the subject of structural materials. | 2 | 2 | PC-1.2, PC-2.2 |

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| **1.32** | | | **Defense of essays** **(Pr).** Defense of essays on the subject of structural materials. | | | 2 | 2 | PC-1.2, PC-2.2 | |
| **1.33** | | | **Homework (IWS).** Writing an essay on a given topic | | | 2 | 40 | PC-1.2, PC- 2.1, PC-2.2 | |
| **1.34** | | | **Preparation for classroom classes (IWS).** Preparation for lectures and practical classes | | | 2 | 40 | PC-1.2, PC- 2.1, PC-2.2 | |
| **2. Intermediate certification (exam)** | | | | | | | | | |
| **2.1** | | | **Preparation for the intermediate certification (Exam).** | | | 2 | 33,65 | PC-1.2, PC- 2.1, PC-2.2 | |
| **2.2** | | | **Contact work with the teacher during the intermediate certification (CWC).** | | | 2 | 2,35 | PC-1.2, PC- 2.1, PC-2.2 | |
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| **5. EVALUATION MATERIALS** | | | | | | | | | |
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| **5.1. List of competencies** | | | | | | | | | |
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| List of competencies, the development of which the study of the discipline is aimed at «Materials for biomedical applications», with an indication of the results of their formation in the process of mastering the educational program, presented in paragraph 3 of this work program | | | | | | | | | |
| **5.2. Typical control questions and tasks** | | | | | | | | | |
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| 1. What materials are classified as structural?  2. What are the general requirements for structural materials?  3. What is the structural strength of materials?  4. What are the main characteristics of the concept of structural strength of the material?  5. Name the criteria for evaluating the structural strength of materials.  6. Name the methods of increasing structural strength.  7. Name the signs of classification of structural materials.  8. What are the requirements for structural steels? | | | | | | | | | |
| **5.3. Fund of evaluation Materials** | | | | | | | | | |
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| A complete list of evaluation materials is provided in the Appendix 1. | | | | | | | | | |
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| **6. MATERIAL, TECHNICAL, EDUCATIONAL AND METHODOLOGICAL SUPPORT OF THE DISCIPLINE (MODULE)** | | | | | | | | | |
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| **6.1. MATERIAL AND TECHNICAL SUPPORT OF THE DISCIPLINE (МОДУЛЯ)** | | | | | | | | | |
| **Name of premises** | | | | | **List of main equipment** | | | | |
| Classroom for lectures and seminars, group and individual consultations, ongoing monitoring and intermediate certification | | | | | Multimedia equipment, specialized furniture, sets of demonstration equipment and educational and visual aids that provide thematic illustrations. | | | | |
| A room for independent work of students | | | | | Computer equipment with the ability to connect to the Internet and provide access to the electronic information and educational environment of the organization. | | | | |
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| **6.2. LIST OF SOFTWARE** | | | | | | | | | |
| 1. |  | Microsoft Windows. Contract No. 32009183466 from 02.07.2021. | | | | | | | |
| 2. |  | Microsoft Office. Contract No. 32009183466 from 02.07.2021. | | | | | | | |

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| **6.3. RECOMMENDED LITERATURE** | | | | |
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| **6.3.1. Basic literature** | | | | |
| 1. |  | Masanskij O. A., Kazakov V. S., Tokmin A. M., Svechnikova L. A., Astaf'eva E. A. Materialovedenie i tekhnologii konstrukcionnyh materialov [Electronic resource]:uchebnik. - Krasnoyarsk: SFU, 2019. - 336 s. – Access mode: https://e.lanbook.com/book/157550 | | |
| 2. |  | Blanter M. S., Sundeev R. V. Materialovedenie nanostrukturirovannyh materialov [Electronic resource]:praktikum. - M.: RTU MIREA, 2018. - – Access mode: http://library.mirea.ru/secret/25092018/1792.iso | | |
| 3. |  | Kapustin V. I., Sigov A. S. Tekhnologii proizvodstva i kontrol' kachestva nanomaterialov i nanostruktur [Electronic resource]:uchebnoe posobie. - M.: MIREA, 2017. - – Access mode: http://library.mirea.ru/secret/21022018/1647.iso | | |
| 4. |  | Zemskov Yu. P. Materialovedenie [Electronic resource]:uchebnoe posobie. - Sankt- Peterburg: Lan', 2019. - 188 s. – Access mode: https://e.lanbook.com/book/113910 | | |
| 5. |  | Сапунов С. В. Материаловедение [Electronic resource]:. - Санкт-Петербург: Лань, 2021. - 208 с. – Access mode: https://e.lanbook.com/book/168740 | | |
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| **6.3.2. Additional literature** | | | | |
| 1. |  | Fetisov G. P. Materialovedenie i tekhnologiya materialov:Rek. Minobrnauki RF v kach. uchebnika dlya vuzov. - M.: Yurajt, 2014. - 767 с. | | |
| 2. |  | Buryj G. G. Materialovedenie. Tekhnologiya konstrukcionnyh materialov [Electronic resource]:uchebno-metodicheskoe posobie. - Omsk: SibADI, 2019. - 222 с. – Access mode: https://e.lanbook.com/book/149463 | | |
| 3. |  | Kondratenko V. S., Kobysh A. N. Innovacionnoe materialovedenie [Electronic resource]:uchebnoe posobie. - M.: RTU MIREA, 2018. - – Access mode: http://library.mirea.ru/secret/06032019/1978.iso | | |
| 4. |  | Mihal'chenkov A. M., Kozarez I. V., Tyureva A. A. Materialovedenie i tekhnologiya konstrukcionnyh materialov [Electronic resource]:uchebnoe posobie. - Bryansk: Bryanskij GAU, 2017. - 391 s. – Access mode: https://e.lanbook.com/book/133028 | | |
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| **6.4. RECOMMENDED LIST OF MODERN PROFESSIONAL DATABASES AND INFORMATION REFERENCE SYSTEMS** | | | | |
| 1. |  | Materials Science Information Portal http://www.materialstoday.com | | |
| 2. |  | Website of the PTI Department of Nanoelectronics https://fks.mirea.ru | | |
| 3. |  | An international resource for the search and exchange of scientific publications  https://www.researchgate.net | | |
| 4. |  | Elektronika NTB - scientific and technical journal  http://www.electronics.ru | | |
| 5. |  | Information and reference portal of scientific publications of domestic and foreign authors «Google Academy»  https://www.scholar.google.ru | | |
| 6. |  | Russian Technological Journal  https://www.rtj.mirea.ru | | |
| 7. |  | Information portal of the International Citation System Scopus  https://www.scopus.com | | |
| 8. |  | Information portal of the International Citation System «Web of Science”  https://www.apps.webofknowledge.com | | |
| 9. |  | Foundation for the Promotion of Innovation  http://www.fasie.ru | | |

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| 10. |  | Ministry of Science and Higher Education of the Russian Federation  https://www.minobrnauki.gov.ru | | |
| 11. |  | Scientific Electronic Library http://www.elibrary.ru | | |
| 12. |  | Information portal of the Russian Science Foundation http://www.rscf.ru | | |
| 13. |  | Russian Foundation for Basic Research https://www.rfbr.ru | | |
| 14. |  | Information portal «Popular nanotechnologies» http://www.popnano.ru | | |
| 15. |  | Nanometer - Nanotechnology community http://www.nanometer.ru | | |
| 16. |  | NanoNewsNet.ru- non-commercial on-line publication dedicated to the nanoindustry http://www.old.nanonewsnet.ru | | |
| 17. |  | Electronic fund of legal and regulatory technical documentation Tekhnoexpert http://www.docs.cntd.ru | | |
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| **6.5. METHODICAL INSTRUCTIONS FOR STUDENTS STUDYING THE DISCIPLINE (MODULE)** | | | | |
| The student’s independent work is aimed at preparing for academic classes and at developing knowledge, skills and abilities provided for in the discipline program.  In accordance with the curriculum, the discipline may include Lectures, practical classes and Laboratory work, as well as the execution and defense of a course project (work). Successful study of the discipline requires attending all types of classes, completing teacher assignments and familiarization with basic and additional literature. Depending on the activities provided for in the curriculum and section 4 of this program, the student chooses methodological guidelines for independent work from the ones listed below.  When preparing for lecture classes, students need to:  before the next lecture, it is necessary to review the summary of the material of the previous Lectures. If you have difficulties in perceiving the material, you should refer to the main literary sources. If it was not possible to understand the material again, then contact the lecturer (according to the schedule of his consultations) or the teacher in practical classes.  Practical classes complete the study of the most important topics of the discipline. They serve to consolidate the studied material, develop the skills and abilities of preparing reports, messages, gaining experience in oral public speeches, conducting discussions, argumentation and defending the propositions put forward, as well as to monitor the degree of readiness of students in the discipline being studied by the teacher.  When preparing for a practical lesson, students have the opportunity to use the advice of a teacher.  When preparing for practical classes, students need to:  bring with you the literature recommended by the teacher for a specific lesson;  before the next practical lesson on the recommended literary sources, work out the theoretical material corresponding to the topic of the lesson;  at the beginning of classes, ask the teacher questions about the material that caused difficulties in understanding and mastering it when solving tasks set for independent solution;  during the seminar, give specific, clear answers to the substance of the questions;  at the training session, bring each task to the final solution, demonstrate an understanding of the calculations (analyses, situations), in case of difficulties, contact the teacher.  Students who have missed classes (regardless of the reasons), who do not have a written solution to problems or are not prepared for this practical lesson, are recommended to come to the teacher’s consultation no later than 2 weeks and report on the topic studied in the lesson.  The methodological guidelines necessary for studying and passing the discipline are given as part of the educational program. | | | | |
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| **6.6. METHODOLOGICAL RECOMMENDATIONS FOR THE TRAINING OF PERSONS WITH LIMITED HEALTH OPPORTUNITIES AND THE DISABLED** | | | | |
| The development of the discipline by students with disabilities can be organized both jointly with other students and in separate groups. | | | | |

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| Special conditions are assumed for students with disabilities to receive education.  The teaching staff gets acquainted with the psychological and physiological characteristics of students with disabilities and persons with disabilities, individual rehabilitation programs for the disabled (if available). If necessary, additional teaching support is provided by tutors, psychologists, social workers, trained assistants.  In accordance with the methodological recommendations of the Ministry of Education and Science of the Russian Federation (approved April 8, 2014 N AK-44/05vn), the course is supposed to use socially active and reflective teaching methods, technologies of socio-cultural rehabilitation in order to assist in establishing full-fledged interpersonal relationships with other students, creating a comfortable psychological climate in the student group. Selection and development of educational materials are made taking into account the provision of material in various forms: auditory, visual, using special technical means and information systems.  Mediamaterials should also be used and adapted taking into account the individual characteristics of the training of persons with disabilities.  The development of the discipline by persons with disabilities is carried out using general and special purpose teaching tools (personal and collective use). Material and technical support provides for the adaptation of classrooms to the needs of persons with disabilities.  The form of certification for students with disabilities is established taking into account individual psychophysical characteristics. For students with HIA, an accessible form of assignment of assessment tools is provided, namely:  - in printed or electronic form (for persons with disorders of the musculoskeletal system);  - in printed or electronic form with enlarged font and contrast (for persons with hearing, speech, vision impairments);  - reading the task aloud by the assistant (for visually impaired persons).  Students with disabilities have increased time to prepare answers to control questions. For such students, an accessible form of providing answers to tasks is provided, namely:  - written on paper or a set of answers on a computer (for persons with hearing and speech impairments);  - choosing an answer from possible options using the services of an assistant (for people with musculoskeletal disorders);  - oral interview (for persons with visual impairments, musculoskeletal system).  If necessary, for students with disabilities, the procedure for evaluating learning outcomes can be carried out in several stages. |

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| MINISTRY OF SCIENCE AND HIGHER EDUCATION OF THE RUSSIAN FEDERATION | | | | | | | | | | | | | | | | | | | | | |
| Federal State Budget Educational Institution of Higher Education  «MIREA – Russian Technological University» | | | | | | | | | | | | | | | | | | | | | |
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| **Institute of Physics and Technology** | | | | | | | | | | | | | | | | | | | | | |
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| Working program of the discipline (module) | | | | | | | | | | | | | | | | | | | | | |
| **Materials and devices for renewable energy** | | | | | | | | | | | | | | | | | | | | | |
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|  | Department leading the training | | | | | |  |  | **Department of Nanoelectronics** | | | | | | | | | | | | |
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|  | Direction of training | | | | | | |  | **11.04.04 Electronics and nanoelectronics** | | | | | | | | | | | | |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  | Profile | | | | | | |  | **Engineering of modern materials for information technology, renewable energy and sensing** | | | | | | | | | | | | |
|  |  |  |  |  |  |  |  |  |
|  | Qualification | | | | |  |  |  | **Master** | | | | | | | | | | | | |
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|  | Form of education | | | | |  |  |  | **Full-time** | | | | | | | | | |  |  |  |
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|  | Total labor intensity | | | |  |  |  |  | **5 credits** | | | | | | | | | |  |  |  |
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| **Distribution of discipline hours and forms of intermediate certification by semesters** | | | | | | | | | | | | | | | | | | | | | |
| Semester | | Credits | Distribution of hours | | | | | | | | | | | | | | | Forms of intermediate attestation | | |  |
| Total | Lectures | | | | Laboratory work | | | Practical classes | Independent work of students | | Contact work during practice and (or) certification | | | Control of training |  |
| 2 | | 5 | 180 | 16 | | | | 0 | | | 48 | 80 | | 2,35 | | | 33,65 | Exam | | |  |
|  |  |  |  |  |  |  |  |  | Moscow 2021 | | | | | | |  |  |  |  |  |  |

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| The program was made by: |  |  |  |  |
|  |  |  |  |  |
| *Doctor of Science in Physico-mathematical Sciences, Professor, A. Yurasov\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_* | | | | |
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| Working program of the discipline | | |  |  |
| **Materials and devices for renewable energy** | | | | |
|  |  |  |  |  |
| it is developed in accordance with FSES HE: | | |  |  |
| Federal State Educational Standard of Higher Education - Magistracy in the Direction of training 11.04.04 Electronics and nanoelectronics (order of the Ministry of Science and Higher Education of the Russian Federation from 22.09.2017. № 959) | | | | |
|  |  |  |  |  |
| it is based on the curriculum: | | |  |  |
| Direction of training: 11.04.04 Electronics and nanoelectronics  Profile: «Engineering of modern materials for information technology, renewable energy and sensing» | | | | |
|  |  |  |  |  |
| The working program was approved at the meeting of the department | | | | |
| **Department of Nanoelectronics** | | | | |
|  |  |  |  |  |
| Minutes of meeting from 02.03.2021 № 3  Head of the Department A. Sigov \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ | | | | |

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| **Approval of the WPD for execution in the next academic year** | | | | |
|  |  |  |  |  |
| The working program was revised, discussed and approved for execution in the 2022-2023 academic year at a meeting of the department | | | | |
| **Department of Nanoelectronics** | | | | |
|  |  |  |  |  |
|  | Minutes of meeting from \_\_ \_\_\_\_\_\_\_\_\_\_ 2022. № \_\_  Head of the Department \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ | | | |
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| **Approval of the WPD for execution in the next academic year** | | | | |
|  |  |  |  |  |
| The working program was revised, discussed and approved for execution in the 2023-2024 academic year at a meeting of the department | | | | |
| **Department of Nanoelectronics** | | | | |
|  |  |  |  |  |
|  | Minutes of meeting from \_\_ \_\_\_\_\_\_\_\_\_\_ 2023. № \_\_  Head of the Department \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ | | | |
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| **Approval of the WPD for execution in the next academic year** | | | | |
|  |  |  |  |  |
| The working program was revised, discussed and approved for execution in the 2024-2025 academic year at a meeting of the department | | | | |
| **Department of Nanoelectronics** | | | | |
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|  | Minutes of meeting from \_\_ \_\_\_\_\_\_\_\_\_\_ 2024. № \_\_  Head of the Department \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ | | | |
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| **Approval of the WPD for execution in the next academic year** | | | | |
|  |  |  |  |  |
| The working program was revised, discussed and approved for execution in the 2025-2026 academic year at a meeting of the department | | | | |
| **Department of Nanoelectronics** | | | | |
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|  | Minutes of meeting from \_\_ \_\_\_\_\_\_\_\_\_\_ 2025. № \_\_  Head of the Department \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ | | | |
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| **1. OBJECTIVES OF MASTERING THE DISCIPLINE (MODULE)** | | | | | |
|  |  |  |  |  |  |
| The discipline «Materials and devices for renewable energy» aims to contribute to the formation of students’ competencies, provided by this work program in accordance with the requirements of FSES HE in the direction of training 11.04.04 Electronics and nanoelectronics, taking into account the specifics of the profile – «Engineering of modern materials for information technology, renewable energy and sensing». | | | | | |
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| **2. PLACE OF DISCIPLINE (MODULE) IN THE STRUCTURE OF THE EDUCATIONAL PROGRAM** | | | | | |
|  | Direction of training: |  | 11.04.04 Electronics and nanoelectronics | | |
|  |
|  | Profile: |  | Engineering of modern materials for information technology, renewable energy and sensing | | |
|  |  |  |
|  | Block: |  | Disciplines (modules) | | |
|  |  |  |
|  | Part: |  | Part of the curriculum formed by the participants of educational | | |
|  |  |  |
|  | Total labor intensity: |  | 5 credits (180 academic hours). | | |
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| **3. THE STUDENT’S COMPETENCIES FORMED AS A RESULT OF MASTERING THE DISCIPLINE (MODULE)** | | | | | |
|  |  |  |  |  |  |
| As a result of mastering the practice, the student must master the following competencies: | | | | | |
| **PC-1** - Capable to apply in-depth knowledge of the structure, physical, physicochemical properties, the purpose of nanomaterials and nanostructures, and methods of measuring their parameters | | | | | |
| **PC-2** - Capable to participate in the development and implementation of modern technological processes, the master of new equipment, technological equipment, the necessary modes of production of micro- and nanoelectronics | | | | | |
|  |  |  |  |  |  |
| **PLANNED RESULTS OF TRAINING IN THE DISCIPLINE (MODULE), CHARACTERIZING THE FORMATION OF COMPETENCIES** | | | | | |
|  |  |  |  |  |  |
| **PC-1 : Capable to apply in-depth knowledge of the structure, physical, physicochemical properties, the purpose of nanomaterials and nanostructures, and methods of measuring their parameters** | | | | | |
|  |  |  |  |  |  |
| **PC-1.2: Analyzes the technological problem at the given norms of technological production, highlighting its basic components and searches for reliable information to solve it for various types of queries** | | | | | |
| **To know:** | | | | | |
| - the role of renewable energy sources in energy supply | | | | | |
| **Be able to:** | | | | | |
| - analyze the problems of renewable energy sources | | | | | |
| **Possess:** | | | | | |
| - the problems of the use of renewable energy sources | | | | | |
|  |  |  |  |  |  |
| **PC-2 : Capable to participate in the development and implementation of modern technological processes, the master of new equipment, technological equipment, the necessary modes of production of micro- and nanoelectronics** | | | | | |

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| **PC-2.1: Participates in the development and implementation of modern technological processes, the development of new equipment, technological equipment, the necessary modes of production of micro- and nanoelectronics products** | | | | | | |
| **To know:** | | | | | | |
| - provisions of the main regulatory documents in the field of renewable energy sources | | | | | | |
| **Be able to:** | | | | | | |
| - calculate the characteristics of renewable energy sources using regulatory documents | | | | | | |
| **Possess:** | | | | | | |
| - terminology in the field of renewable energy sources | | | | | | |
|  |  |  |  |  |  |  |
| **PC-2.2: Evaluates optimal processes and modes in the development of electronics products** | | | | | | |
| **To know:** | | | | | | |
| - fundamentals of calculating the efficiency of using renewable energy sources | | | | | | |
| **Be able to:** | | | | | | |
| - calculate the efficiency of using renewable energy sources | | | | | | |
| **Possess:** | | | | | | |
| - skills of analyzing information about the technical parameters of power plants using renewable energy sources | | | | | | |
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| **AS A RESULT OF STUDYING THE DISCIPLINE (MODULE), THE STUDENT MUST** | | | | | | |
|  |  |  |  |  |  |  |
| **To know:** | | | | | | |
| - fundamentals of calculating the efficiency of using renewable energy sources | | | | | | |
| - provisions of the main regulatory documents in the field of renewable energy sources | | | | | | |
| - the role of renewable energy sources in energy supply | | | | | | |
| **Be able to:** | | | | | | |
| - calculate the efficiency of using renewable energy sources | | | | | | |
| - calculate the characteristics of renewable energy sources using regulatory documents | | | | | | |
| - analyze the problems of renewable energy sources | | | | | | |
| **Possess:** | | | | | | |
| - skills of analyzing information about the technical parameters of power plants using renewable energy sources | | | | | | |
| - terminology in the field of renewable energy sources | | | | | | |
| - the problems of the use of renewable energy sources | | | | | | |
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| **4. STRUCTURE AND CONTENT OF THE DISCIPLINE (MODULE)** | | | | | | |
|  |  |  |  |  |  |  |
| During the training sessions, the organization ensures the development of students’ teamwork skills, interpersonal communication, decision-making and leadership qualities. | | | | | | |
| **Code** | **Name of sections and topics /type of classes/** | | **Semester** | **Academic Hours** | **Competencies** | |
| **1. Renewable energy sources** | | | | | | |

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| **1.1** | **Lecture** **1.** **Introduction. General characteristics of the energy industry.** **(Lec).** Energy and its quality. The energy balance of the planet. Increasing rates of energy consumption. Renewable and non-renewable energy sources. Regulatory acts. | 2 | 2 | PC-1.2, PC-2.1 |
| **1.2** | **Lecture** **2.** **Use of solar energy.** **(Lec).** General characteristics of solar energy. Solar heat supply systems. Conversion of solar energy into electricity. Solar photovoltaic converters. Thermophotoelectric converters. Problems of the industry. Environmental impact. | 2 | 2 | PC-1.2, PC- 2.1, PC-2.2 |
| **1.3** | **Lecture** **3.** **Use of wind energy.** **(Lec).** Development of wind energy in the world. Calculation of a wind power plant. Calculation of wind energy resources. Problems of the industry. Environmental impact. | 2 | 2 | PC-1.2, PC- 2.1, PC-2.2 |
| **1.4** | **Lecture** **4.** **Geothermal energy.** **(Lec).** Sources of heat in the bowels of the Earth and patterns of its transmission. Methodology for assessing geothermal resources. The use of geothermal energy to generate electricity. Problems of the industry. Environmental impact. | 2 | 2 | PC-1.2, PC- 2.1, PC-2.2 |
| **1.5** | **Lecture** **5.** **Biomass energy.** **(Lec).** The concept of biomass. The use of biomass for the production of thermal and electrical energy. Biofuels. Classification of biofuels. Technology and schemes for obtaining biofuels. | 2 | 2 | PC-1.2, PC- 2.1, PC-2.2 |
| **1.6** | **Lecture** **6.** **The energy of small rivers. Energy resources of the ocean.** **(Lec).** Hydropower potential and its use. The basic principles of creating small hydroelectric power plants. Energy and power. Tidal power plants. The use of wave energy. The use of ocean thermal energy. General information about the use of tidal energy. The power of tidal currents and tidal rise of water. Using the energy of ocean currents, differences in temperature and salinity. Ocean Thermal Energy Resources. | 2 | 2 | PC-1.2, PC- 2.1, PC-2.2 |
| **1.7** | **Lecture** **7.** **Secondary energy resources.** **(Lec).** Classification of secondary energy resources: fuel, thermal, overpressure. The energy potential of VER in Russia. Economic efficiency of the use of VER in various sectors of the national economy. Reduced costs. Heat pumps. Environmental problems. | 2 | 2 | PC-1.2, PC- 2.1, PC-2.2 |

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| **1.8** | **Lecture** **8.** **Energy storage and transmission.** **(Lec).** Specific problems of energy storage and transmission from renewable sources. Biological accumulation. Heat storage. Accumulation of electricity. Fuel cells. Energy transfer. Classification of types of energy transmission. | 2 | 2 | PC-1.2, PC- 2.1, PC-2.2 |
| **1.9** | **Performing practical tasks (Pr).** PR 1. Classification and potential of renewable energy sources | 2 | 2 | PC-1.2, PC- 2.1, PC-2.2 |
| **1.10** | **Performing practical tasks (Pr).** PR 2. Solar heaters for water and air. Passive and active solar heating systems. Industrial application of solar energy. Photovoltaic generation. Solar power plants | 2 | 2 | PC-1.2, PC- 2.1, PC-2.2 |
| **1.11** | **Performing practical tasks (Pr).** PR 3. Ideal and real wind turbines. Wind power stations. | 2 | 2 | PC-1.2, PC- 2.1, PC-2.2 |
| **1.12** | **Performing practical tasks (Pr).** PR 4. Geothermal power plants. Estimation of the thermal power of the geothermal array. | 2 | 2 | PC-1.2, PC- 2.1, PC-2.2 |
| **1.13** | **Performing practical tasks (Pr).** PR 5. Calculation of biogas generators. Energy farms. Autonomous thermal power complexes. Integrated district heating stations. | 2 | 2 | PC-1.2, PC- 2.1, PC-2.2 |
| **1.14** | **Performing practical tasks (Pr).** PR 6. Determination of the economic efficiency of the construction of a small hydroelectric power plant. Characteristics of hydraulic turbines. The use of wave energy. The use of ocean thermal energy. | 2 | 2 | PC-1.2, PC- 2.1, PC-2.2 |
| **1.15** | **Performing practical tasks (Pr).** PR 7. Fuel secondary energy resources. Heat pump installations. | 2 | 2 | PC-1.2, PC- 2.1, PC-2.2 |
| **1.16** | **Performing practical tasks (Pr).** PR 8. Energy storage. | 2 | 2 | PC-1.2, PC- 2.1, PC-2.2 |
| **1.17** | **Performing practical tasks (Pr).** PR 9. Calculation of costs for disposal of NiMH and Li-ion batteries. | 2 | 2 | PC-1.2, PC- 2.1, PC-2.2 |
| **1.18** | **Oral interview (Pr).** Conducting a survey based on the materials of the lecture | 2 | 2 | PC-1.2, PC- 2.1, PC-2.2 |
| **1.19** | **Oral interview (Pr).** Conducting a survey based on the materials of the lecture | 2 | 2 | PC-1.2, PC- 2.1, PC-2.2 |
| **1.20** | **Oral interview (Pr).** Conducting a survey based on the materials of the lecture | 2 | 2 | PC-1.2, PC- 2.1, PC-2.2 |
| **1.21** | **Oral interview (Pr).** Conducting a survey based on the materials of the lecture | 2 | 2 | PC-1.2, PC- 2.1, PC-2.2 |

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| **1.22** | **Oral interview (Pr).** Conducting a survey based on the materials of the lecture | | 2 | 2 | PC-1.2, PC- 2.1, PC-2.2 | |
| **1.23** | **Oral interview (Pr).** Conducting a survey based on the materials of the lecture | | 2 | 2 | PC-1.2, PC- 2.1, PC-2.2 | |
| **1.24** | **Oral interview (Pr).** Conducting a survey based on the materials of the lecture | | 2 | 2 | PC-1.2, PC- 2.1, PC-2.2 | |
| **1.25** | **Oral interview (Pr).** Conducting a survey based on the materials of the lecture | | 2 | 2 | PC-1.2, PC- 2.1, PC-2.2 | |
| **1.26** | **Defense of essays** **(Pr).** Defense of essays | | 2 | 2 | PC-1.2, PC- 2.1, PC-2.2 | |
| **1.27** | **Defense of essays** **(Pr).** Defense of essays | | 2 | 2 | PC-1.2, PC- 2.1, PC-2.2 | |
| **1.28** | **Defense of essays** **(Pr).** Defense of essays | | 2 | 2 | PC-1.2, PC- 2.1, PC-2.2 | |
| **1.29** | **Defense of essays** **(Pr).** Defense of essays | | 2 | 2 | PC-1.2, PC- 2.1, PC-2.2 | |
| **1.30** | **Defense of essays** **(Pr).** Defense of essays | | 2 | 2 | PC-1.2, PC- 2.1, PC-2.2 | |
| **1.31** | **Defense of essays** **(Pr).** Defense of essays | | 2 | 2 | PC-1.2, PC- 2.1, PC-2.2 | |
| **1.32** | **Solution of the control work (Pr).** Control questions. | | 2 | 2 | PC-1.2, PC- 2.1, PC-2.2 | |
| **1.33** | **Writing a home written work (essay, abstract) (IWS).** Writing essays. | | 2 | 40 | PC-1.2, PC- 2.1, PC-2.2 | |
| **1.34** | **Preparation for classroom classes (IWS).** Repetition of lecture and practical materials. | | 2 | 40 | PC-2.1, PC-2.2 | |
| **2. Intermediate certification (exam)** | | | | | | |
| **2.1** | **Preparation for the intermediate certification (Exam).** | | 2 | 33,65 | PC-1.2, PC- 2.1, PC-2.2 | |
| **2.2** | **Contact work with the teacher during the intermediate certification (CWC).** | | 2 | 2,35 | PC-1.2, PC- 2.1, PC-2.2 | |
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| **5. EVALUATION MATERIALS** | | | | | | |
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| **5.1. List of competencies** | | | | | | |
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| List of competencies, the development of which the study of the discipline is aimed at «Materials and devices for renewable energy», with an indication of the results of their formation in the process of mastering the educational program, presented in paragraph 3 of this work program | | | | | | |
| **5.2. Typical control questions and tasks** | | | | | | |
|  |  |  |  |  |  |  |
| 1. The current state and prospects for the development of renewable energy.  2. The main regulatory acts of the Russian Federation in the field of renewable energy.  3.Energy efficiency and energy conservation. Basic concepts.  4. Methods of risk assessment from RES.  5. Calculations of the main categories of renewable energy potential.  6. Methods for calculating the arrival of solar radiation on a horizontal and arbitrarily oriented area on the Earth's surface at an arbitrarily taken point. Dependence of solar radiation on time and latitude of the terrain.  7. Absorption in the atmosphere (optical mass). Optimal orientation of the solar radiation receiver.  8.Main types of solar power plants. | | | | | | |

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| 9. The main types of energy losses and factors affecting the efficiency of the solar cell.  Solar cell designs.  Basic technical requirements for solar cell materials.  10.Rigid and flexible solar cells. The efficiency of the main types of solar cells. Photovoltaic power plants.  11. The main environmental problems of solar energy. Advantages and disadvantages.  12. Basic concepts and definitions of wind energy. Sources of wind energy potential. Wind energy conversion. Wind power plants.  13. The main characteristics of wind and methods of their determination. Dependence of wind parameters on altitude and time. The wind rose. The main categories of wind energy potential and methods of their calculation.  14. The main technical schemes of wind energy use and their classification.  15. The main environmental problems of wind energy. Advantages and disadvantages.  16. Using the energy of water flow movement Basic principles of using water energy.  17. The energy of sea waves and currents. Sources of potential and their features. The energy and power of the wave and methods of its use. Ideal and real waves and methods of their description. Energy spectrum (wave power distribution) 18. Tidal energy. Sources of potential and their features. The influence of the Sun and Moon on the tides. High tide in the open ocean and near the shores. A tidal wave. Energy of tidal currents and methods of its calculation. oln. Methods of using wave energy in continuous wave motion.  19. The main environmental problems of tidal power plants.  20. Sources based on geothermal energy. Geothermal energy, basic concepts and definitions. Sources of geothermal energy potential. Fundamentals of geophysics.  21. The thermal field of the Earth.  22. Methods of radiation of geothermal resources and their classification.  23. The use of geothermal energy: opportunities and needs.  24. The technique of extracting the heat of the Earth.  25. The main schemes of the technological process  26. Biomass as an energy source. Biomass energy. Basic concepts and definitions. Classification of biofuels.  27. Purpose of energy accumulators and principles of accumulation: biological, chemical, thermal, electrical, mechanical. The main characteristics of batteries. | | | |
| **5.3. Fund of evaluation Materials** | | | |
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| A complete list of evaluation materials is provided in the Appendix 1. | | | |
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| **6. MATERIAL, TECHNICAL, EDUCATIONAL AND METHODOLOGICAL SUPPORT OF THE DISCIPLINE (MODULE)** | | | |
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| **6.1. MATERIAL AND TECHNICAL SUPPORT OF THE DISCIPLINE (МОДУЛЯ)** | | | |
| **Name of premises** | | **List of main equipment** | |
| Classroom for lectures and seminars, group and individual consultations, ongoing monitoring and intermediate certification | | Multimedia equipment, specialized furniture, sets of demonstration equipment and educational and visual aids that provide thematic illustrations. | |
| A room for independent work of students | | Computer equipment with the ability to connect to the Internet and provide access to the electronic information and educational environment of the organization. | |
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| **6.2. LIST OF SOFTWARE** | | | |

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| 1. |  | Microsoft Windows. Contract No. 32009183466 from 02.07.2021. | | |
| 2. |  | Microsoft Office. Contract No. 32009183466 from 02.07.2021. | | |
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| **6.3. RECOMMENDED LITERATURE** | | | | |
|  |  |  |  |  |
| **6.3.1. Basic literature** | | | | |
| 1. |  | Yudaev I. V., Daus Yu. V., Gamaga V. V. Vozobnovlyaemye istochniki energii [Electronic resource]:uchebnik. - Sankt-Peterburg: Lan', 2020. - 328 s. – Access mode: https://e.lanbook.com/book/140747 | | |
|  |  |  |  |  |
| **6.3.2. Additional literature** | | | | |
| 1. |  | da Roza A. Vozobnovlyaemye istochniki energii. Fiziko-tekhnicheskie osnovy:Ucheb. posobie. - Dolgoprudnyj: Izd. Dom " Intellekt", 2010. - 703 s. | | |
| 2. |  | Elistratov V. V. Ispol'zovanie vozobnovlyaemoj energii [Electronic resource]:[ucheb. posobie]. - SPb.: Izd-vo Politekhn. un-ta, 2010. - 225 – Access mode: https://lib.rucont.ru/efd/266848 | | |
| 3. |  | Germanovich V., Turilin A. Al'ternativnye istochniki energii. Prakticheskie konstrukcii po ispol'zovaniyu energii vetra, solnca, vody, zemli, biomassy:. - Sankt- Peterburg: Nauka i tekhnika, 2011. - 320 с. | | |
| 4. |  | Martyushev D. A., Ilyushin P. YU. Vozobnovlyaemye istochniki energii [Electronic resource]:uchebnoe posobie. - Perm': PNIPU, 2015. - 136 s. – Access mode: https://e.lanbook.com/book/160508 | | |
| 5. |  | Gubarev, Arzamascev Netradicionnye i vozobnovlyaemye istochniki energii [Electronic resource]:ucheb. posobie. - Lipeck: LGTU, 2014. - 77 – Access mode: https://lib.rucont.ru/efd/302212 | | |
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| **6.4. RECOMMENDED LIST OF MODERN PROFESSIONAL DATABASES AND INFORMATION REFERENCE SYSTEMS** | | | | |
| 1. |  | Materials Science Information Portal http://www.materialstoday.com | | |
| 2. |  | Website of the PTI Department of Nanoelectronics https://fks.mirea.ru | | |
| 3. |  | Database Web of Science  http://www.webofknowledge.com | | |
| 4. |  | Journal «Nano- and Microsystem Technology»  http://www.microsystems.ru | | |
| 5. |  | National Research Center «Kurchatov Institute»  http://www.kcsni.nrcki.ru | | |
| 6. |  | Elektronika NTB - scientific and technical journal  http://www.electronics.ru | | |
| 7. |  | Information and reference portal of scientific publications of domestic and foreign authors «Google Academy»  https://www.scholar.google.ru | | |
| 8. |  | Russian Technological Journal  https://www.rtj.mirea.ru | | |
| 9. |  | Information portal of the International Citation System Scopus  https://www.scopus.com | | |
| 10. |  | Information portal of the International Citation System «Web of Science”  https://www.apps.webofknowledge.com | | |
| 11. |  | Foundation for the Promotion of Innovation  http://www.fasie.ru | | |

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| 12. |  | Ministry of Science and Higher Education of the Russian Federation  https://www.minobrnauki.gov.ru | | |
| 13. |  | Natural Science educational Portal http://www.en.edu.ru | | |
| 14. |  | Scientific Electronic Library http://www.elibrary.ru | | |
| 15. |  | Information portal of the Russian Science Foundation http://www.rscf.ru | | |
| 16. |  | Russian Foundation for Basic Research https://www.rfbr.ru | | |
| 17. |  | Electronic fund of legal and regulatory technical documentation Tekhnoexpert http://www.docs.cntd.ru | | |
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| **6.5. METHODICAL INSTRUCTIONS FOR STUDENTS STUDYING THE DISCIPLINE (MODULE)** | | | | |
| The student’s independent work is aimed at preparing for academic classes and at developing knowledge, skills and abilities provided for in the discipline program.  In accordance with the curriculum, the discipline may include Lectures, practical classes and Laboratory work, as well as the execution and defense of a course project (work). Successful study of the discipline requires attending all types of classes, completing teacher assignments and familiarization with basic and additional literature. Depending on the activities provided for in the curriculum and section 4 of this program, the student chooses methodological guidelines for independent work from the ones listed below.  When preparing for lecture classes, students need to:  before the next lecture, it is necessary to review the summary of the material of the previous Lectures. If you have difficulties in perceiving the material, you should refer to the main literary sources. If it was not possible to understand the material again, then contact the lecturer (according to the schedule of his consultations) or the teacher in practical classes.  Practical classes complete the study of the most important topics of the discipline. They serve to consolidate the studied material, develop the skills and abilities of preparing reports, messages, gaining experience in oral public speeches, conducting discussions, argumentation and defending the propositions put forward, as well as to monitor the degree of readiness of students in the discipline being studied by the teacher.  When preparing for a practical lesson, students have the opportunity to use the advice of a teacher.  When preparing for practical classes, students need to:  bring with you the literature recommended by the teacher for a specific lesson;  before the next practical lesson on the recommended literary sources, work out the theoretical material corresponding to the topic of the lesson;  at the beginning of classes, ask the teacher questions about the material that caused difficulties in understanding and mastering it when solving tasks set for independent solution;  during the seminar, give specific, clear answers to the substance of the questions;  at the training session, bring each task to the final solution, demonstrate an understanding of the calculations (analyses, situations), in case of difficulties, contact the teacher.  Students who have missed classes (regardless of the reasons), who do not have a written solution to problems or are not prepared for this practical lesson, are recommended to come to the teacher’s consultation no later than 2 weeks and report on the topic studied in the lesson.  The methodological guidelines necessary for studying and passing the discipline are given as part of the educational program. | | | | |
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| **6.6. METHODOLOGICAL RECOMMENDATIONS FOR THE TRAINING OF PERSONS WITH LIMITED HEALTH OPPORTUNITIES AND THE DISABLED** | | | | |
| The development of the discipline by students with disabilities can be organized both jointly with other students and in separate groups. Special conditions are assumed for students with disabilities to receive education. | | | | |

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| The teaching staff gets acquainted with the psychological and physiological characteristics of students with disabilities and persons with disabilities, individual rehabilitation programs for the disabled (if available). If necessary, additional teaching support is provided by tutors, psychologists, social workers, trained assistants.  In accordance with the methodological recommendations of the Ministry of Education and Science of the Russian Federation (approved April 8, 2014 N AK-44/05vn), the course is supposed to use socially active and reflective teaching methods, technologies of socio-cultural rehabilitation in order to assist in establishing full-fledged interpersonal relationships with other students, creating a comfortable psychological climate in the student group. Selection and development of educational materials are made taking into account the provision of material in various forms: auditory, visual, using special technical means and information systems.  Mediamaterials should also be used and adapted taking into account the individual characteristics of the training of persons with disabilities.  The development of the discipline by persons with disabilities is carried out using general and special purpose teaching tools (personal and collective use). Material and technical support provides for the adaptation of classrooms to the needs of persons with disabilities.  The form of certification for students with disabilities is established taking into account individual psychophysical characteristics. For students with HIA, an accessible form of assignment of assessment tools is provided, namely:  - in printed or electronic form (for persons with disorders of the musculoskeletal system);  - in printed or electronic form with enlarged font and contrast (for persons with hearing, speech, vision impairments);  - reading the task aloud by the assistant (for visually impaired persons).  Students with disabilities have increased time to prepare answers to control questions. For such students, an accessible form of providing answers to tasks is provided, namely:  - written on paper or a set of answers on a computer (for persons with hearing and speech impairments);  - choosing an answer from possible options using the services of an assistant (for people with musculoskeletal disorders);  - oral interview (for persons with visual impairments, musculoskeletal system).  If necessary, for students with disabilities, the procedure for evaluating learning outcomes can be carried out in several stages. |

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| Federal State Budget Educational Institution of Higher Education  «MIREA – Russian Technological University» | | | | | | | | | | | | | | | | | | | | | |
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| Working program of the discipline (module) | | | | | | | | | | | | | | | | | | | | | |
| **Materials and devices for sensing** | | | | | | | | | | | | | | | | | | | | | |
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|  | Department leading the training | | | | | |  |  | **Department of Nanoelectronics** | | | | | | | | | | | | |
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|  | Direction of training | | | | | | |  | **11.04.04 Electronics and nanoelectronics** | | | | | | | | | | | | |
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|  | Profile | | | | | | |  | **Engineering of modern materials for information technology, renewable energy and sensing** | | | | | | | | | | | | |
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|  | Qualification | | | | |  |  |  | **Master** | | | | | | | | | | | | |
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|  | Form of education | | | | |  |  |  | **Full-time** | | | | | | | | | |  |  |  |
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|  | Total labor intensity | | | |  |  |  |  | **4 credits** | | | | | | | | | |  |  |  |
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| **Distribution of discipline hours and forms of intermediate certification by semesters** | | | | | | | | | | | | | | | | | | | | | |
| Semester | | Credits | Distribution of hours | | | | | | | | | | | | | | | Forms of intermediate attestation | | |  |
| Total | Lectures | | | | Laboratory work | | | Practical classes | Independent work of students | | Contact work during practice and (or) certification | | | Control of training |  |
| 3 | | 4 | 144 | 16 | | | | 0 | | | 32 | 78 | | 0,25 | | | 17,75 | Test | | |  |
| including for practicing practical skills | | | | 0 | | | | 0 | | | 16 | 0 | | 0 | | | 0 |  | | |  |
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| The program was made by: |  |  |  |  |
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| *Doctor of Science in Physico-mathematical Sciences, Associate Professor, Фетисов Л.Ю. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_* | | | | |
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| Working program of the discipline | | |  |  |
| **Materials and devices for sensing** | | | | |
|  |  |  |  |  |
| it is developed in accordance with FSES HE: | | |  |  |
| Federal State Educational Standard of Higher Education - Magistracy in the Direction of training 11.04.04 Electronics and nanoelectronics (order of the Ministry of Science and Higher Education of the Russian Federation from 22.09.2017. № 959) | | | | |
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| it is based on the curriculum: | | |  |  |
| Direction of training: 11.04.04 Electronics and nanoelectronics  Profile: «Engineering of modern materials for information technology, renewable energy and sensing» | | | | |
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| The working program was approved at the meeting of the department | | | | |
| **Department of Nanoelectronics** | | | | |
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| Minutes of meeting from 02.03.2021 № 3  Head of the Department A. Sigov \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ | | | | |

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| **Approval of the WPD for execution in the next academic year** | | | | |
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| The working program was revised, discussed and approved for execution in the 2022-2023 academic year at a meeting of the department | | | | |
| **Department of Nanoelectronics** | | | | |
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|  | Minutes of meeting from \_\_ \_\_\_\_\_\_\_\_\_\_ 2022. № \_\_  Head of the Department \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ | | | |
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| **Approval of the WPD for execution in the next academic year** | | | | |
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| The working program was revised, discussed and approved for execution in the 2023-2024 academic year at a meeting of the department | | | | |
| **Department of Nanoelectronics** | | | | |
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|  | Minutes of meeting from \_\_ \_\_\_\_\_\_\_\_\_\_ 2023. № \_\_  Head of the Department \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ | | | |
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| **Approval of the WPD for execution in the next academic year** | | | | |
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| The working program was revised, discussed and approved for execution in the 2024-2025 academic year at a meeting of the department | | | | |
| **Department of Nanoelectronics** | | | | |
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|  | Minutes of meeting from \_\_ \_\_\_\_\_\_\_\_\_\_ 2024. № \_\_  Head of the Department \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ | | | |
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| **Approval of the WPD for execution in the next academic year** | | | | |
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| The working program was revised, discussed and approved for execution in the 2025-2026 academic year at a meeting of the department | | | | |
| **Department of Nanoelectronics** | | | | |
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|  | Minutes of meeting from \_\_ \_\_\_\_\_\_\_\_\_\_ 2025. № \_\_  Head of the Department \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ | | | |
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| **1. OBJECTIVES OF MASTERING THE DISCIPLINE (MODULE)** | | | | | |
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| The discipline «Materials and devices for sensing» aims to contribute to the formation of students’ competencies, provided by this work program in accordance with the requirements of FSES HE in the direction of training 11.04.04 Electronics and nanoelectronics, taking into account the specifics of the profile – «Engineering of modern materials for information technology, renewable energy and sensing». | | | | | |
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| **2. PLACE OF DISCIPLINE (MODULE) IN THE STRUCTURE OF THE EDUCATIONAL PROGRAM** | | | | | |
|  | Direction of training: |  | 11.04.04 Electronics and nanoelectronics | | |
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|  | Profile: |  | Engineering of modern materials for information technology, renewable energy and sensing | | |
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|  | Block: |  | Disciplines (modules) | | |
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|  | Part: |  | Part of the curriculum formed by the participants of educational | | |
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|  | Total labor intensity: |  | 4 credits (144 academic hours). | | |
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| **3. THE STUDENT’S COMPETENCIES FORMED AS A RESULT OF MASTERING THE DISCIPLINE (MODULE)** | | | | | |
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| As a result of mastering the practice, the student must master the following competencies: | | | | | |
| **PC-2** - Capable to participate in the development and implementation of modern technological processes, the master of new equipment, technological equipment, the necessary modes of production of micro- and nanoelectronics | | | | | |
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| **PLANNED RESULTS OF TRAINING IN THE DISCIPLINE (MODULE), CHARACTERIZING THE FORMATION OF COMPETENCIES** | | | | | |
|  |  |  |  |  |  |
| **PC-2 : Capable to participate in the development and implementation of modern technological processes, the master of new equipment, technological equipment, the necessary modes of production of micro- and nanoelectronics** | | | | | |
|  |  |  |  |  |  |
| **PC-2.1: Participates in the development and implementation of modern technological processes, the development of new equipment, technological equipment, the necessary modes of production of micro- and nanoelectronics products** | | | | | |
| **To know:** | | | | | |
| - modern sensor devices | | | | | |
| **Be able to:** | | | | | |
| - develop and implement modern sensor devices | | | | | |
| **Possess:** | | | | | |
| - skills in the development and implementation of modern sensor devices | | | | | |
|  |  |  |  |  |  |
| **PC-2.2: Evaluates optimal processes and modes in the development of electronics products** | | | | | |
| **To know:** | | | | | |
| - the main processes of sensor development | | | | | |
| **Be able to:** | | | | | |
| - evaluate optimal processes for developing sensor devices | | | | | |
| **Possess:** | | | | | |
| - skills in choosing optimal processes for developing sensor devices | | | | | |

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| **AS A RESULT OF STUDYING THE DISCIPLINE (MODULE), THE STUDENT MUST** | | | | | | |
|  |  |  |  |  |  |  |
| **To know:** | | | | | | |
| - the main processes of sensor development | | | | | | |
| - modern sensor devices | | | | | | |
| **Be able to:** | | | | | | |
| - evaluate optimal processes for developing sensor devices | | | | | | |
| - develop and implement modern sensor devices | | | | | | |
| **Possess:** | | | | | | |
| - skills in choosing optimal processes for developing sensor devices | | | | | | |
| - skills in the development and implementation of modern sensor devices | | | | | | |
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| **4. STRUCTURE AND CONTENT OF THE DISCIPLINE (MODULE)** | | | | | | |
|  |  |  |  |  |  |  |
| During the training sessions, the organization ensures the development of students’ teamwork skills, interpersonal communication, decision-making and leadership qualities. | | | | | | |
| **Code** | **Name of sections and topics /type of classes/** | | **Semester** | **Academic Hours** | **Competencies** | |
| **1. Sensor devices and materials** | | | | | | |
| **1.1** | **Lecture** **1.** **Introduction** **(Lec).** The history of sensors and microsystem technology. Terminology. The main types of sensors. | | 3 | 2 | PC-2.1, PC-2.2 | |
| **1.2** | **Oral interview (Pr).** Questions about the lecture 1 | | 3 | 2 (including 1 for practicing practical skills) | PC-2.1, PC-2.2 | |
| **1.3** | **Preparation for classroom classes (IWS).** Control questions about the lecture 1 | | 3 | 2 | PC-2.1, PC-2.2 | |
| **1.4** | **Homework (IWS).** Search for articles on the topic of lecture 1. | | 3 | 7 | PC-2.2 | |
| **1.5** | **Lecture** **2.** **Sensor classifications (Lec).** Basic physical principles of sensor operation. Types of classifications. Classification according to the physical principle of action. By functional purpose. By the nature of the transformation. Types of sensitive elements. | | 3 | 2 | PC-2.1, PC-2.2 | |
| **1.6** | **Oral interview (Pr).** Questions about the lecture 2 | | 3 | 2 (including 1 for practicing practical skills) | PC-2.1, PC-2.2 | |
| **1.7** | **Oral interview (Pr).** Questions about the lecture 2 | | 3 | 2 (including 1 for practicing practical skills) | PC-2.2, PC-2.1 | |
| **1.8** | **Preparation for classroom classes (IWS).** Control questions about the lecture 2 | | 3 | 2 | PC-2.2, PC-2.1 | |
| **1.9** | **Homework (IWS).** Search for articles on the topic of lecture 2. | | 3 | 7 | PC-2.2 | |

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| **1.10** | **Lecture** **3.** **Sensor Characteristics (Lec).** Technical specifications. Metrological characteristics. Conversion function. Conversion factor. The sensitivity of the conversion. Sensitivity threshold. The conversion ranges. Hysteresis. Non-linearity. Reproducibility. Reliability. | 3 | 2 | PC-2.1, PC-2.2 |
| **1.11** | **Oral interview (Pr).** Questions about the lecture 3 | 3 | 2 (including 1 for practicing practical skills) | PC-2.1, PC-2.2 |
| **1.12** | **Oral interview (Pr).** Questions about the lecture 3 | 3 | 2 (including 1 for practicing practical skills) | PC-2.1, PC-2.2 |
| **1.13** | **Preparation for classroom classes (IWS).** Control questions about the lecture 3 | 3 | 2 | PC-2.1, PC-2.2 |
| **1.14** | **Homework (IWS).** Search for articles on the topic of lecture 3. | 3 | 8 | PC-2.2 |
| **1.15** | **Lecture** **4.** **Capacitive sensors (Lec).** Types of capacitive sensors. Basic constructions. Materials of capacitive sensors. | 3 | 2 | PC-2.1, PC-2.2 |
| **1.16** | **Oral interview (Pr).** Questions about the lecture 4 | 3 | 2 (including 1 for practicing practical skills) | PC-2.1, PC-2.2 |
| **1.17** | **Solution of the control work (Pr).** Questions about the lecture 1-4 | 3 | 2 (including 1 for practicing practical skills) | PC-2.1, PC-2.2 |
| **1.18** | **Preparation for classroom classes (IWS).** Control questions for the lecture 4 | 3 | 2 | PC-2.1, PC-2.2 |
| **1.19** | **Homework (IWS).** Search for articles on the topic of lecture 4. | 3 | 8 | PC-2.2 |
| **1.20** | **Lecture** **5.** **Magnetic sensors (Lec).** Types of magnetic sensors. Basic constructions. Magnetic materials. | 3 | 2 | PC-2.1 |
| **1.21** | **Oral interview (Pr).** Questions about the lecture 5 | 3 | 2 (including 1 for practicing practical skills) | PC-2.1, PC-2.2 |
| **1.22** | **Oral interview (Pr).** Questions about the lecture 5 | 3 | 2 (including 1 for practicing practical skills) | PC-2.1, PC-2.2 |
| **1.23** | **Preparation for classroom classes (IWS).** Control questions about the lecture 5 | 3 | 2 | PC-2.1, PC-2.2 |
| **1.24** | **Homework (IWS).** Search for articles on the topic of lecture 5. | 3 | 8 | PC-2.2 |
| **1.25** | **Lecture** **6.** **Piezoelectric sensors (Lec).** Types of piezoelectric sensors. Basic constructions. Piezoelectrics. | 3 | 2 | PC-2.1, PC-2.2 |
| **1.26** | **Oral interview (Pr).** Questions about the lecture 6 | 3 | 2 (including 1 for practicing practical skills) | PC-2.1, PC-2.2 |

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| **1.27** | **Oral interview (Pr).** Questions about the lecture 6 | | 3 | 2 (including 1 for practicing practical skills) | PC-2.1, PC-2.2 | |
| **1.28** | **Preparation for classroom classes (IWS).** Control questions about the lecture 6 | | 3 | 2 | PC-2.1, PC-2.2 | |
| **1.29** | **Homework (IWS).** Search for articles on the topic of lecture 6. | | 3 | 8 | PC-2.2 | |
| **1.30** | **Lecture** **7.** **Resistive sensors (Lec).** Types of resistive sensors. Basic constructions. Materials. | | 3 | 2 | PC-2.1, PC-2.2 | |
| **1.31** | **Oral interview (Pr).** Questions about the lecture 7 | | 3 | 2 (including 1 for practicing practical skills) | PC-2.1, PC-2.2 | |
| **1.32** | **Oral interview (Pr).** Questions about the lecture 7 | | 3 | 2 (including 1 for practicing practical skills) | PC-2.1, PC-2.2 | |
| **1.33** | **Preparation for classroom classes (IWS).** Control questions about the lecture 7 | | 3 | 2 | PC-2.1, PC-2.2 | |
| **1.34** | **Homework (IWS).** Search for articles on the topic of lecture 7. | | 3 | 8 | PC-2.2 | |
| **1.35** | **Lecture** **8.** **Sensors for surfactants (Lec).** Surface acoustic waves. Types of sensors. Basic constructions. Materials. | | 3 | 2 | PC-2.1, PC-2.2 | |
| **1.36** | **Oral interview (Pr).** Questions about the lecture 8 | | 3 | 2 (including 1 for practicing practical skills) | PC-2.1, PC-2.2 | |
| **1.37** | **Oral interview (Pr).** Questions about the lecture 8 | | 3 | 2 (including 1 for practicing practical skills) | PC-2.1, PC-2.2 | |
| **1.38** | **Preparation for classroom classes (IWS).** Control questions about the lecture 8 | | 3 | 2 | PC-2.1, PC-2.2 | |
| **1.39** | **Homework (IWS).** Search for articles on the topic of lecture 8. | | 3 | 8 | PC-2.2 | |
| **1.40** | **Solution of the control work (Pr).** Questions about the lecture 1-8 | | 3 | 2 (including 1 for practicing practical skills) | PC-2.1, PC-2.2 | |
| **2. Intermediate certification (Test)** | | | | | | |
| **2.1** | **Preparation for the intermediate certification (Test).** | | 3 | 17,75 | PC-2.1, PC-2.2 | |
| **2.2** | **Contact work with the teacher during the intermediate certification (CWC).** | | 3 | 0,25 | PC-2.1, PC-2.2 | |
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| **5. EVALUATION MATERIALS** | | | | | | |
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| **5.1. List of competencies** | | | | | | |
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| List of competencies, the development of which the study of the discipline is aimed at «Materials and devices for sensing», with an indication of the results of their formation in the process of mastering the educational program, presented in paragraph 3 of this work program | | | | | | |
| **5.2. Typical control questions and tasks** | | | | | | |
|  |  |  |  |  |  |  |
| 1. What types of sensors do you know?  2. What technological characteristics of sensors do you know?  3. What magnetic materials are used in sensors? | | | | | | |

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| 4. What is the Hall effect?  5. What resistive sensors do you know?  6. What piezoelectric materials used in sensors do you know?  7. What is magnetic hysteresis?  8. What materials are called ferromagnets?  9. What is magnetization? | | | | | |
| **5.3. Fund of evaluation Materials** | | | | | |
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| A complete list of evaluation materials is provided in the Appendix 1. | | | | | |
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| **6. MATERIAL, TECHNICAL, EDUCATIONAL AND METHODOLOGICAL SUPPORT OF THE DISCIPLINE (MODULE)** | | | | | |
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| **6.1. MATERIAL AND TECHNICAL SUPPORT OF THE DISCIPLINE (МОДУЛЯ)** | | | | | |
| **Name of premises** | | | | **List of main equipment** | |
| Classroom for lectures and seminars, group and individual consultations, ongoing monitoring and intermediate certification | | | | Multimedia equipment, specialized furniture, sets of demonstration equipment and educational and visual aids that provide thematic illustrations. | |
| A room for independent work of students | | | | Computer equipment with the ability to connect to the Internet and provide access to the electronic information and educational environment of the organization. | |
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| **6.2. LIST OF SOFTWARE** | | | | | |
| 1. |  | Microsoft Windows. Contract No. 32009183466 from 02.07.2021. | | | |
| 2. |  | Microsoft Office. Contract No. 32009183466 from 02.07.2021. | | | |
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| **6.3. RECOMMENDED LITERATURE** | | | | | |
|  |  |  |  |  |  |
| **6.3.1. Basic literature** | | | | | |
| 1. |  | Savickij V. A. Mikrosistemnaya tekhnika i ee komponenty [Electronic resource]:uchebnoe posobie. - M.: MIREA, 2016. - – Access mode: http://library.mirea.ru/secret/e\_1066.iso | | | |
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| **6.3.2. Additional literature** | | | | | |
| 1. |  | Mal'cev P. P. Nano- i mikrosistemnaya tekhnika. Ot issledovanij k razrabotkam:Sbornik statej. - M.: Tekhnosfera, 2005. - 590 s. | | | |
| 2. |  | Varadan V., Vinoj K., Dzhoze K. VCH MEMS i ih primenenie:. - M.: Tekhnosfera, 2004. - 525 s. | | | |
| 3. |  | Pevtsov E. F., Krutov V. V. Osnovy avtomatizirovannogo proektirovaniya SVCH ustrojstv i sistem [Electronic resource]:uchebnoe posobie. - M.: RTU MIREA, 2018. - – Access mode: http://library.mirea.ru/secret/06032019/1975.iso | | | |
| 4. |  | Pevtsov E. F., Demenkova T. A., Al'-Natah R. I. Osnovy modelirovaniya i proektirovaniya MEMS v SAPR CoventorWare [Electronic resource]:uchebnoe posobie. - M.: MIREA, 2016. - – Access mode: http://library.mirea.ru/secret/ab/1242.iso | | | |
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| **6.4. RECOMMENDED LIST OF MODERN PROFESSIONAL DATABASES AND INFORMATION REFERENCE SYSTEMS** | | | | | |
| 1. |  | News and analytical portal "Vremya elektroniki "  http://www.russianelectronics.ru | | | |
| 2. |  | Journal «Nano- and Microsystem Technology»  http://www.microsystems.ru | | | |

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| 3. |  | National Research Center «Kurchatov Institute»  http://www.kcsni.nrcki.ru | | |
| 4. |  | An international resource for the search and exchange of scientific publications  https://www.researchgate.net | | |
| 5. |  | Elektronika NTB - scientific and technical journal  http://www.electronics.ru | | |
| 6. |  | Website of the PTI Department of Nanoelectronics https://fks.mirea.ru | | |
| 7. |  | Russian Technological Journal  https://www.rtj.mirea.ru | | |
| 8. |  | Ministry of Science and Higher Education of the Russian Federation  https://www.minobrnauki.gov.ru | | |
| 9. |  | Natural Science educational Portal http://www.en.edu.ru | | |
| 10. |  | Scientific Electronic Library http://www.elibrary.ru | | |
| 11. |  | COMSOL Multiphysics® Software for multiphysical modeling https://www.COMSOL.ru | | |
| 12. |  | Information portal of the Russian Science Foundation http://www.rscf.ru | | |
| 13. |  | Nanometer - Nanotechnology community http://www.nanometer.ru | | |
| 14. |  | NanoNewsNet.ru- non-commercial on-line publication dedicated to the nanoindustry http://www.old.nanonewsnet.ru | | |
| 15. |  | Electronic fund of legal and regulatory technical documentation Tekhnoexpert http://www.docs.cntd.ru | | |
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| **6.5. METHODICAL INSTRUCTIONS FOR STUDENTS STUDYING THE DISCIPLINE (MODULE)** | | | | |
| The student’s independent work is aimed at preparing for academic classes and at developing knowledge, skills and abilities provided for in the discipline program.  In accordance with the curriculum, the discipline may include Lectures, practical classes and Laboratory work, as well as the execution and defense of a course project (work). Successful study of the discipline requires attending all types of classes, completing teacher assignments and familiarization with basic and additional literature. Depending on the activities provided for in the curriculum and section 4 of this program, the student chooses methodological guidelines for independent work from the ones listed below.  When preparing for lecture classes, students need to:  before the next lecture, it is necessary to review the summary of the material of the previous Lectures. If you have difficulties in perceiving the material, you should refer to the main literary sources. If it was not possible to understand the material again, then contact the lecturer (according to the schedule of his consultations) or the teacher in practical classes.  Practical classes complete the study of the most important topics of the discipline. They serve to consolidate the studied material, develop the skills and abilities of preparing reports, messages, gaining experience in oral public speeches, conducting discussions, argumentation and defending the propositions put forward, as well as to monitor the degree of readiness of students in the discipline being studied by the teacher.  When preparing for a practical lesson, students have the opportunity to use the advice of a teacher.  When preparing for practical classes, students need to:  bring with you the literature recommended by the teacher for a specific lesson;  before the next practical lesson on the recommended literary sources, work out the theoretical material corresponding to the topic of the lesson;  at the beginning of classes, ask the teacher questions about the material that caused difficulties in understanding and mastering it when solving tasks set for independent solution;  during the seminar, give specific, clear answers to the substance of the questions; | | | | |

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| at the training session, bring each task to the final solution, demonstrate an understanding of the calculations (analyses, situations), in case of difficulties, contact the teacher.  Students who have missed classes (regardless of the reasons), who do not have a written solution to problems or are not prepared for this practical lesson, are recommended to come to the teacher’s consultation no later than 2 weeks and report on the topic studied in the lesson.  The methodological guidelines necessary for studying and passing the discipline are given as part of the educational program. | | |
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| **6.6. METHODOLOGICAL RECOMMENDATIONS FOR THE TRAINING OF PERSONS WITH LIMITED HEALTH OPPORTUNITIES AND THE DISABLED** | | |
| The development of the discipline by students with disabilities can be organized both jointly with other students and in separate groups. Special conditions are assumed for students with disabilities to receive education.  The teaching staff gets acquainted with the psychological and physiological characteristics of students with disabilities and persons with disabilities, individual rehabilitation programs for the disabled (if available). If necessary, additional teaching support is provided by tutors, psychologists, social workers, trained assistants.  In accordance with the methodological recommendations of the Ministry of Education and Science of the Russian Federation (approved April 8, 2014 N AK-44/05vn), the course is supposed to use socially active and reflective teaching methods, technologies of socio-cultural rehabilitation in order to assist in establishing full-fledged interpersonal relationships with other students, creating a comfortable psychological climate in the student group. Selection and development of educational materials are made taking into account the provision of material in various forms: auditory, visual, using special technical means and information systems.  Mediamaterials should also be used and adapted taking into account the individual characteristics of the training of persons with disabilities.  The development of the discipline by persons with disabilities is carried out using general and special purpose teaching tools (personal and collective use). Material and technical support provides for the adaptation of classrooms to the needs of persons with disabilities.  The form of certification for students with disabilities is established taking into account individual psychophysical characteristics. For students with HIA, an accessible form of assignment of assessment tools is provided, namely:  - in printed or electronic form (for persons with disorders of the musculoskeletal system);  - in printed or electronic form with enlarged font and contrast (for persons with hearing, speech, vision impairments);  - reading the task aloud by the assistant (for visually impaired persons).  Students with disabilities have increased time to prepare answers to control questions. For such students, an accessible form of providing answers to tasks is provided, namely:  - written on paper or a set of answers on a computer (for persons with hearing and speech impairments);  - choosing an answer from possible options using the services of an assistant (for people with musculoskeletal disorders);  - oral interview (for persons with visual impairments, musculoskeletal system).  If necessary, for students with disabilities, the procedure for evaluating learning outcomes can be carried out in several stages. | | |

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| MINISTRY OF SCIENCE AND HIGHER EDUCATION OF THE RUSSIAN FEDERATION | | | | | | | | | | | | | | | | | | | | | |
| Federal State Budget Educational Institution of Higher Education  «MIREA – Russian Technological University» | | | | | | | | | | | | | | | | | | | | | |
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| Working program of the discipline (module) | | | | | | | | | | | | | | | | | | | | | |
| **Characterization techniques for materials and devices** | | | | | | | | | | | | | | | | | | | | | |
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|  | Department leading the training | | | | | |  |  | **Department of Nanoelectronics** | | | | | | | | | | | | |
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|  | Direction of training | | | | | | |  | **11.04.04 Electronics and nanoelectronics** | | | | | | | | | | | | |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  | Profile | | | | | | |  | **Engineering of modern materials for information technology, renewable energy and sensing** | | | | | | | | | | | | |
|  |  |  |  |  |  |  |  |  |
|  | Qualification | | | | |  |  |  | **Master** | | | | | | | | | | | | |
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|  | Form of education | | | | |  |  |  | **Full-time** | | | | | | | | | |  |  |  |
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|  | Total labor intensity | | | |  |  |  |  | **8 credits** | | | | | | | | | |  |  |  |
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| **Distribution of discipline hours and forms of intermediate certification by semesters** | | | | | | | | | | | | | | | | | | | | | |
| Semester | | Credits | Distribution of hours | | | | | | | | | | | | | | | Forms of intermediate attestation | | |  |
| Total | Lectures | | | | Laboratory work | | | Practical classes | Independent work of students | | Contact work during practice and (or) certification | | | Control of training |  |
| 2 | | 4 | 144 | 16 | | | | 0 | | | 32 | 78 | | 0,25 | | | 17,75 | Test | | |  |
| 3 | | 4 | 144 | 16 | | | | 16 | | | 16 | 60 | | 2,35 | | | 33,65 | Exam | | |  |
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| The program was made by: |  |  |  |  |
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| *Ph.D. Physics and Mathematics, Senior lecturer, S. Lavrov \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_* | | | | |
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| Working program of the discipline | | |  |  |
| **Characterization techniques for materials and devices** | | | | |
|  |  |  |  |  |
| it is developed in accordance with FSES HE: | | |  |  |
| Federal State Educational Standard of Higher Education - Magistracy in the Direction of training 11.04.04 Electronics and nanoelectronics (order of the Ministry of Science and Higher Education of the Russian Federation from 22.09.2017. № 959) | | | | |
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| it is based on the curriculum: | | |  |  |
| Direction of training: 11.04.04 Electronics and nanoelectronics  Profile: «Engineering of modern materials for information technology, renewable energy and sensing» | | | | |
|  |  |  |  |  |
| The working program was approved at the meeting of the department | | | | |
| **Department of Nanoelectronics** | | | | |
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| Minutes of meeting from 02.03.2021 № 3  Head of the Department A. Sigov \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ | | | | |

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| **Approval of the WPD for execution in the next academic year** | | | | |
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| The working program was revised, discussed and approved for execution in the 2022-2023 academic year at a meeting of the department | | | | |
| **Department of Nanoelectronics** | | | | |
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|  | Minutes of meeting from \_\_ \_\_\_\_\_\_\_\_\_\_ 2022. № \_\_  Head of the Department \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ | | | |
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| **Approval of the WPD for execution in the next academic year** | | | | |
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| The working program was revised, discussed and approved for execution in the 2023-2024 academic year at a meeting of the department | | | | |
| **Department of Nanoelectronics** | | | | |
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|  | Minutes of meeting from \_\_ \_\_\_\_\_\_\_\_\_\_ 2023. № \_\_  Head of the Department \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ | | | |
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| **Approval of the WPD for execution in the next academic year** | | | | |
|  |  |  |  |  |
| The working program was revised, discussed and approved for execution in the 2024-2025 academic year at a meeting of the department | | | | |
| **Department of Nanoelectronics** | | | | |
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|  | Minutes of meeting from \_\_ \_\_\_\_\_\_\_\_\_\_ 2024. № \_\_  Head of the Department \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ | | | |
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| **Approval of the WPD for execution in the next academic year** | | | | |
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| The working program was revised, discussed and approved for execution in the 2025-2026 academic year at a meeting of the department | | | | |
| **Department of Nanoelectronics** | | | | |
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|  | Minutes of meeting from \_\_ \_\_\_\_\_\_\_\_\_\_ 2025. № \_\_  Head of the Department \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ | | | |
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| **1. OBJECTIVES OF MASTERING THE DISCIPLINE (MODULE)** | | | | | |
|  |  |  |  |  |  |
| The discipline «Characterization techniques for materials and devices» aims to contribute to the formation of students’ competencies, provided by this work program in accordance with the requirements of FSES HE in the direction of training 11.04.04 Electronics and nanoelectronics, taking into account the specifics of the profile – «Engineering of modern materials for information technology, renewable energy and sensing». | | | | | |
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| **2. PLACE OF DISCIPLINE (MODULE) IN THE STRUCTURE OF THE EDUCATIONAL PROGRAM** | | | | | |
|  | Direction of training: |  | 11.04.04 Electronics and nanoelectronics | | |
|  |
|  | Profile: |  | Engineering of modern materials for information technology, renewable energy and sensing | | |
|  |  |  |
|  | Block: |  | Disciplines (modules) | | |
|  |  |  |
|  | Part: |  | Part of the curriculum formed by the participants of educational | | |
|  |  |  |
|  | Total labor intensity: |  | 8 credits (288 academic hours). | | |
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| **3. THE STUDENT’S COMPETENCIES FORMED AS A RESULT OF MASTERING THE DISCIPLINE (MODULE)** | | | | | |
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| As a result of mastering the practice, the student must master the following competencies: | | | | | |
| **PC-1** - Capable to apply in-depth knowledge of the structure, physical, physicochemical properties, the purpose of nanomaterials and nanostructures, and methods of measuring their parameters | | | | | |
|  |  |  |  |  |  |
| **PLANNED RESULTS OF TRAINING IN THE DISCIPLINE (MODULE), CHARACTERIZING THE FORMATION OF COMPETENCIES** | | | | | |
|  |  |  |  |  |  |
| **PC-1 : Capable to apply in-depth knowledge of the structure, physical, physicochemical properties, the purpose of nanomaterials and nanostructures, and methods of measuring their parameters** | | | | | |
|  |  |  |  |  |  |
| **PC-1.1: Applies in-depth knowledge of the structure, physical, physicochemical properties, the purpose of nanomaterials and nanostructures, and methods for measuring their parameters in the field of electronics** | | | | | |
| **To know:** | | | | | |
| - basic techniques and approaches for studying the resistivity of semiconductor materials and structures, as well as the distribution of charge carrier concentrations in them | | | | | |
| **Be able to:** | | | | | |
| - apply methods and approaches for the study of semiconductor materials by galvanomagnetic and probe techniques, build the simplest physical and mathematical models describing the conductivity of semiconductor materials | | | | | |
| **Possess:** | | | | | |
| - skills in choosing techniques and approaches for determining the conductivity of semiconductor materials and structures | | | | | |
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| **PC-1.2: Analyzes the technological problem at the given norms of technological production, highlighting its basic components and searches for reliable information to solve it for various types of queries** | | | | | |

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| **To know:** | | | | | | |
| - the main methods and approaches for studying the parameters of nonequilibrium charge carriers in semiconductor materials, as well as optical methods for measuring the properties of semiconductors | | | | | | |
| **Be able to:** | | | | | | |
| - apply techniques and approaches to the study of semiconductor materials using optical techniques, build the simplest physical and mathematical models describing the interactions of light and semiconductor structures | | | | | | |
| **Possess:** | | | | | | |
| - skills in choosing techniques and approaches for estimating the lifetime and mobility of charge carriers in semiconductor materials and structures | | | | | | |
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| **AS A RESULT OF STUDYING THE DISCIPLINE (MODULE), THE STUDENT MUST** | | | | | | |
|  |  |  |  |  |  |  |
| **To know:** | | | | | | |
| - the main methods and approaches for studying the parameters of nonequilibrium charge carriers in semiconductor materials, as well as optical methods for measuring the properties of semiconductors | | | | | | |
| - basic techniques and approaches for studying the resistivity of semiconductor materials and structures, as well as the distribution of charge carrier concentrations in them | | | | | | |
| **Be able to:** | | | | | | |
| - apply techniques and approaches to the study of semiconductor materials using optical techniques, build the simplest physical and mathematical models describing the interactions of light and semiconductor structures | | | | | | |
| - apply methods and approaches for the study of semiconductor materials by galvanomagnetic and probe techniques, build the simplest physical and mathematical models describing the conductivity of semiconductor materials | | | | | | |
| **Possess:** | | | | | | |
| - skills in choosing techniques and approaches for estimating the lifetime and mobility of charge carriers in semiconductor materials and structures | | | | | | |
| - skills in choosing techniques and approaches for determining the conductivity of semiconductor materials and structures | | | | | | |
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| **4. STRUCTURE AND CONTENT OF THE DISCIPLINE (MODULE)** | | | | | | |
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| During the training sessions, the organization ensures the development of students’ teamwork skills, interpersonal communication, decision-making and leadership qualities. | | | | | | |
| **Code** | **Name of sections and topics /type of classes/** | | **Semester** | **Academic Hours** | **Competencies** | |
| **1. Measurement of the resistivity of semiconductors** | | | | | | |
| **1.1** | **Lecture** **1.** **Measurement of electrophysical parameters of semiconductor materials (Lec).** Methods for measuring the resistivity of semiconductor materials. Two-probe method. Influence of inhomogeneities of the resistivity of the sample. Four-probe measurement method. Theory of the method. Linear arrangement of the probes. The location of the probes along the vertices of the square. Electrical diagram and measurement procedure. | | 2 | 2 | PC-1.1 | |
| **1.2** | **Performing practical tasks (Pr).** Measurement of resistivity (part 1) | | 2 | 2 | PC-1.1 | |

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| **1.3** | **Performing practical tasks (Pr).** Measurement of resistivity (part 2) | 2 | 2 | PC-1.1 |
| **1.4** | **Lecture** **2.** **A three-probe method based on measuring the breakdown voltage of a metal—semiconductor point contact (Lec).** The peculiarity of the application of the three-probe method. The scheme of the method. The error of the three-probe method. Probe material. The profile of the tip. Load on the probe. Thermal effects. Sample surface treatment. Application of the four-probe method to samples of simple geometric shape. A sample of a semi-infinite volume with a conductive or insulating boundary. Thin plate. Two-layer structure. A thin layer. | 2 | 2 | PC-1.1 |
| **1.5** | **Performing practical tasks (Pr).** Measurement by the four-probe method | 2 | 2 | PC-1.1 |
| **1.6** | **Performing practical tasks (Pr).** Using the four-probe method | 2 | 2 | PC-1.1 |
| **1.7** | **Lecture** **3.** **Measurement of the resistivity of diffusion, epitaxial and ion-doped layers by the four-probe method (Lec).** The basis of the method. Sequential removal of layers. Influence of the conduction surface. Ways to remove layers. A diffuse layer isolated by a p-n junction. Spreading resistance method. Theory of the method. Measurement of the resistivity distribution. Using the correction function | 2 | 2 | PC-1.1 |
| **1.8** | **Performing practical tasks (Pr).** Measurement by the four-probe method | 2 | 2 | PC-1.1 |
| **1.9** | **Performing practical tasks (Pr).** Application of the spreading method | 2 | 2 | PC-1.1 |
| **1.10** | **Lecture** **4.** **Van der Pau method and two-combination four-probe method (Lec).** The Van der Pau method. Two-combination four-probe method. The measurement scheme of the two-combination method. A system of probes on the surface. High-frequency non-contact measurement methods. Induction method. The design of the experimental installation of the induction method. The capacitive method. The design of the experimental installation of the capacitive method. | 2 | 2 | PC-1.1 |
| **1.11** | **Performing practical tasks (Pr).** Measurement of the specific conductivity of epitaxial layers | 2 | 2 | PC-1.1 |
| **1.12** | **Performing practical tasks (Pr).** Using the induction method | 2 | 2 | PC-1.1 |

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| **1.13** | **Lecture** **5.** **Measurement of the concentration and mobility of charge carriers in semiconductor materials.** **(Lec).** The Hall effect. Magneto resistive effect. Transverse thermolytic effect. Thermolytic effect. Methods of measuring the EMF of the Hall. The geometry of the samples. Location of conducting contacts. Application of the four-probe method. Using a constant and variable field. | | 2 | 2 | PC-1.1 | |
| **1.14** | **Performing practical tasks (Pr).** Hall coefficient in a strong magnetic field. | | 2 | 2 | PC-1.1 | |
| **1.15** | **Performing practical tasks (Pr).** Calculation of the EMF Hall. | | 2 | 2 | PC-1.1 | |
| **1.16** | **Lecture** **6.** **Determination of the concentration of donors and acceptors by the temperature dependence of the concentration of charge carriers (Lec).** Methods of analysis of temperature dependences of charge carrier concentration. Calculation of theoretical dependences of electron concentration on temperature. Measurement of the charge carrier concentration distribution in diffuse, epitaxial and ion-doped layers. Analysis of a model of a semiconductor sample with an inhomogeneous distribution of the concentration of charge carriers. The Hall EMF of an inhomogeneous sample. | | 2 | 2 | PC-1.1 | |
| **1.17** | **Performing practical tasks (Pr).** Application of the Hall current method. | | 2 | 2 | PC-1.1 | |
| **1.18** | **Performing practical tasks (Pr).** Hall EMF for inhomogeneous samples | | 2 | 2 | PC-1.1 | |
| **1.19** | **Lecture** **7.** **Measurement of the mobility distribution of charge carriers in diffuse, epitaxial and ion-doped layers.** **(Lec).** Sequential removal of layers of the semiconductor structure. Determination of the effective mobility of charge carriers. Determination of the concentration of donors and acceptors by the Hall mobility of charge carriers. Assessment of the concentration of ionized impurities. Building Brooks-Herring dependencies. | | 2 | 2 | PC-1.1 | |
| **1.20** | **Performing practical tasks (Pr).** Features of the mobility distribution of charge carriers in ion-doped layers | | 2 | 2 | PC-1.1 | |
| **1.21** | **Performing practical tasks (Pr).** Features of the mobility distribution of charge carriers in epitaxial layers | | 2 | 2 | PC-1.1 | |

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| **1.22** | **Lecture** **8.** **Measuring the mobility of charge carriers by the Hall current method.** **(Lec).** Hall current method. Calculation of the Hall current. Experimental installation for measuring the Hall current. Correction functions for calculating the Hall current. Measurement of the mobility of charge carriers by the geometric magnetoresistance current method. Geometric resistance method. Calculation of the mobility of geometric resistance. Experimental setup for measuring mobility by geometric resistance method. | 2 | 2 | PC-1.1 |
| **1.23** | **Performing practical tasks (Pr).** Features of the mobility distribution of charge carriers in diffuse layers. | 2 | 2 | PC-1.1 |
| **1.24** | **Performing practical tasks (Pr).** Application of the geometric magnetoresistance method | 2 | 2 | PC-1.1 |
| **1.25** | **Homework (IWS).** Homework on the topic of the lecture | 2 | 40 | PC-1.1 |
| **1.26** | **Preparation for classroom classes (IWS).** Preparation for lectures and practical classes | 2 | 38 | PC-1.1 |
| **2. Intermediate certification (Test)** | | | | |
| **2.1** | **Preparation for the intermediate certification (Test).** | 2 | 17,75 | PC-1.1 |
| **2.2** | **Contact work with the teacher during the intermediate certification (CWC).** | 2 | 0,25 | PC-1.1 |
| **3. Determination of the parameters of nonequilibrium charge carriers in semiconductors. Optical methods for measuring semiconductor parameters** | | | | |
| **3.1** | **Lecture** **9.** **Optical methods for measuring parameters of semiconductor materials.** **(Lec).** Stationary photoconductivity. Spectral dependence of photoconductivity. Methods for determining parameters. Determination of semiconductor parameters by measuring stationary photoconductivity. | 3 | 2 | PC-1.2 |
| **3.2** | **Performing practical tasks (Pr).** Determination of semiconductor parameters. Stationary conductivity. | 3 | 2 | PC-1.2 |
| **3.3** | **Lecture** **10.** **Determination of the diffuse length by the photocurrent of the short circuit of the p-n junction.** **(Lec).** Measurement of diffuse length by spectral dependence of excitation and photoluminescence emission. The method of surface photo-EMF. | 3 | 2 | PC-1.2 |
| **3.4** | **Performing practical tasks (Pr).** Short-circuit photocurrent of the p-n junction. Analysis of the surface photo-EMF technique. | 3 | 2 | PC-1.2 |

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| **3.5** | **Lecture** **11.** **Measurement of semiconductor parameters by photoconductivity attenuation method** **(Lec).** Scheme of an experimental setup for measuring the lifetime of charge carriers. Scheme of an experimental setup for measuring the surface recombination of charge carriers. | 3 | 2 | PC-1.2 |
| **3.6** | **Performing practical tasks (Pr).** Application of the phase method of measuring the lifetime of charge carriers. Pumping-sensing technique | 3 | 2 | PC-1.2 |
| **3.7** | **Lecture** **12.** **Phase and frequency methods of measuring the lifetime of charge carriers (Lec).** Phase shift between the excitation light and the photocurrent. Frequency dependence of the photocurrent. Photocurrent through the Schottky contact. Photoluminescence. | 3 | 2 | PC-1.2 |
| **3.8** | **Performing practical tasks (Pr).** Determination of diffuse length. Using the frequency method to measure the lifetime of charge carriers | 3 | 2 | PC-1.2 |
| **3.9** | **Lecture** **13.** **Control of the structural parameters of semiconductor materials.** **(Lec).** Infrared interference. The physical basis of the method. Selection of the spectral range. Requirements for the parameters of the substrate. The range of measured thicknesses. Thickness measurement error | 3 | 2 | PC-1.2 |
| **3.10** | **Performing practical tasks (Pr).** Experimental methods for studying the properties of semiconductors. Calculation of optical reflection from a sample of a complex structure. | 3 | 2 | PC-1.2 |
| **3.11** | **Lecture** **14.** **Interference in the visible region of the spectrum** **(Lec).** A method for processing interferograms and calculating the thickness of the epitaxial layer. Infrared Fourier spectroscopy. The principle of the method. Application of the method for accurate estimation of crystal parameters. | 3 | 2 | PC-1.2 |
| **3.12** | **Performing practical tasks (Pr).** Using the Fourier spectroscopy method. Interferograms. | 3 | 2 | PC-1.2 |
| **3.13** | **Lecture** **15.** **Infrared ellipsometry (Lec).** The essence of the method. The scheme of the experimental installation. Examples of the results obtained. Data processing and analysis. | 3 | 2 | PC-1.2 |
| **3.14** | **Performing practical tasks (Pr).** Features of the application of the infrared ellipsometry technique. Analysis of ellipsometry results | 3 | 2 | PC-1.2 |

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| **3.15** | **Lecture** **16.** **Non-optical methods for analyzing the properties of semiconductors. (Lec).** The method of staining the train. Measurement of deviation from flatness and control. Secondary ion mass spectroscopy. Electron spectroscopy for chemical analysis. Electronic Auger spectroscopy. Electron probe X-ray microanalysis. | | 3 | 2 | PC-1.2 | |
| **3.16** | **Performing practical tasks (Pr).** The method of staining the train. Auger spectroscopy method | | 3 | 2 | PC-1.2 | |
| **3.17** | **Homework (IWS).** Homework on the topic of the lecture | | 3 | 30 | PC-1.2 | |
| **3.18** | **Preparation for classroom classes (IWS).** Preparation for Lecture, practical and laboratory classes | | 3 | 30 | PC-1.2 | |
| **3.19** | **Laboratory work 1** **(LW).** Determination of the resistivity of semiconductor materials by probe methods | | 3 | 4 (including 4 for practicing practical skills) | PC-1.2 | |
| **3.20** | **Laboratory work 2** **(LW).** Measurement of resistivity of semiconductor materials by Van der Pau method | | 3 | 4 (including 4 for practicing practical skills) | PC-1.2 | |
| **3.21** | **Laboratory work 3** **(LW).** Measurement of the concentration and mobility of charge carriers by optical methods | | 3 | 4 (including 4 for practicing practical skills) | PC-1.2 | |
| **3.22** | **Laboratory work 4** **(LW).** Measurement of parameters of semiconductor films by infrared interference | | 3 | 4 (including 4 for practicing practical skills) | PC-1.2 | |
| **4. Intermediate certification (exam)** | | | | | | |
| **4.1** | **Preparation for the intermediate certification (Exam).** | | 3 | 33,65 | PC-1.2 | |
| **4.2** | **Contact work with the teacher during the intermediate certification (CWC).** | | 3 | 2,35 | PC-1.2 | |
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| **5. EVALUATION MATERIALS** | | | | | | |
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| **5.1. List of competencies** | | | | | | |
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| List of competencies, the development of which the study of the discipline is aimed at «Characterization techniques for materials and devices», with an indication of the results of their formation in the process of mastering the educational program, presented in paragraph 3 of this work program | | | | | | |
| **5.2. Typical control questions and tasks** | | | | | | |
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| Exam questions (2 Semester):  \*Methods for measuring the resistivity of semiconductor materials.  \*Hall effect.  \*Parameters of nonequilibrium charge carriers.  \*Methods for measuring the drift mobility of non-basic charge carriers.  \*Measurement of the diffusion coefficient.  \*Methods for measuring the diffusion length of non-basic charge carriers.  \*Moving light beam method.  \*Measurement of the lifetime of charge carriers by the method of conduction modulation in point contact. | | | | | | |

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| Exam questions (3 Semester):  \*Determination of semiconductor parameters by measuring stationary photoconductivity.  \*Determination of the diffusion length  \*Measurement of diffusion length  \*Optical constants.  \*Experimental methods for determining optical constants.  \*Spectral devices and devices for the study of optical properties.  \*Measurement of the concentration and mobility of charge carriers by optical methods.  \*The Faraday effect.  \*Electron spectroscopy for chemical analysis.  \*Electronic Auger spectroscopy.  \*Electron probe X-ray microanalysis. | | | | | |
| **5.3. Fund of evaluation Materials** | | | | | |
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| A complete list of evaluation materials is provided in the Appendix 1. | | | | | |
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| **6. MATERIAL, TECHNICAL, EDUCATIONAL AND METHODOLOGICAL SUPPORT OF THE DISCIPLINE (MODULE)** | | | | | |
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| **6.1. MATERIAL AND TECHNICAL SUPPORT OF THE DISCIPLINE (МОДУЛЯ)** | | | | | |
| **Name of premises** | | | | **List of main equipment** | |
| Classroom for lectures and seminars, group and individual consultations, ongoing monitoring and intermediate certification | | | | Multimedia equipment, specialized furniture, sets of demonstration equipment and educational and visual aids that provide thematic illustrations. | |
| Specialized Educational and Scientific Laboratory of Femtosecond Optics for Nanotechnology | | | | Optical spectroscopy of reflection and transmission coefficients, Optical spectroscopy of the magneto-optical Kerr effect, Synchronous broadband tunable femtosecond pulse generator, Femtosecond laser tunable system | |
| Specialized Educational and Scientific Laboratory of Femtosecond Optics for Nanotechnology | | | | Microwave signal spectrum analyzer, High-sensitivity camera, Optical nitrogen-helium cryostat with thermal stabilization unit,  Monochromator, Scientific Complex "Nonlinear optical properties of materials", Scientific Complex "Electron microscopy", Near-field optical microscopy System | |
| A room for independent work of students | | | | Computer equipment with the ability to connect to the Internet and provide access to the electronic information and educational environment of the organization. | |
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| **6.2. LIST OF SOFTWARE** | | | | | |
| 1. |  | Microsoft Windows. Contract No. 32009183466 from 02.07.2021. | | | |
| 2. |  | Microsoft Office. Contract No. 32009183466 from 02.07.2021. | | | |
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| **6.3. RECOMMENDED LITERATURE** | | | | | |

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| **6.3.1. Basic literature** | | | | |
| 1. |  | Timofeev V. B. Opticheskaya spektroskopiya ob"emnyh poluprovodnikov i nanostruktur [Electronic resource]:. - Sankt-Peterburg: Lan', 2021. - 512 s. – Access mode: https://e.lanbook.com/book/168751 | | |
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| **6.3.2. Additional literature** | | | | |
| 1. |  | Pavlov L. P. Metody izmereniya parametrov poluprovodnikovyh materialov:Ucheb. dlya vuzov po spec. "Poluprovodnikovye i mikroelektronnye pribory". - M.: Vyssh. shk., 1987. - 238 s. | | |
| 2. |  | Starosel'skij V. I. Fizika poluprovodnikovyh priborov mikroelektroniki:uchebnoe posobie dlya vuzov. - M.: YUrajt, 2014. - 463 s. | | |
| 3. |  | Shalimova K. V. Fizika poluprovodnikov [Electronic resource]:. - Sankt-Peterburg: Lan', 2010. - 384 s. – Access mode: https://e.lanbook.com/books/element.php? pl1\_cid=25&pl1\_id=648 | | |
| 4. |  | Bonch-Bruevich V. L., Kalashnikov S. G. Fizika poluprovodnikov:ucheb. posobie dlya vuzov. - M.: Nauka, 1990. - 686 s. | | |
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| **6.4. RECOMMENDED LIST OF MODERN PROFESSIONAL DATABASES AND INFORMATION REFERENCE SYSTEMS** | | | | |
| 1. |  | Materials Science Information Portal http://www.materialstoday.com | | |
| 2. |  | Website of the PTI Department of Nanoelectronics https://fks.mirea.ru | | |
| 3. |  | Database Web of Science  http://www.webofknowledge.com | | |
| 4. |  | News and analytical portal "Vremya elektroniki "  http://www.russianelectronics.ru | | |
| 5. |  | Journal «Nano- and Microsystem Technology»  http://www.microsystems.ru | | |
| 6. |  | Elektronika NTB - scientific and technical journal  http://www.electronics.ru | | |
| 7. |  | Russian Technological Journal  https://www.rtj.mirea.ru | | |
| 8. |  | Magazine portal of the A.F. Ioffe Institute of Physics and Technology  https://www.journals.ioffe.ru | | |
| 9. |  | Scientific Electronic Library http://www.elibrary.ru | | |
| 10. |  | Information portal «Popular nanotechnologies» http://www.popnano.ru | | |
| 11. |  | Nanometer - Nanotechnology community http://www.nanometer.ru | | |
| 12. |  | NanoNewsNet.ru- non-commercial on-line publication dedicated to the nanoindustry http://www.old.nanonewsnet.ru | | |
| 13. |  | Electronic fund of legal and regulatory technical documentation Tekhnoexpert http://www.docs.cntd.ru | | |
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| **6.5. METHODICAL INSTRUCTIONS FOR STUDENTS STUDYING THE DISCIPLINE (MODULE)** | | | | |
| The student’s independent work is aimed at preparing for academic classes and at developing knowledge, skills and abilities provided for in the discipline program.  In accordance with the curriculum, the discipline may include Lectures, practical classes and Laboratory work, as well as the execution and defense of a course project (work). Successful study of the discipline requires attending all types of classes, completing teacher assignments and familiarization with basic and additional literature. Depending on the activities provided for in the curriculum and section 4, | | | | |

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| in this program, the student chooses methodological guidelines for independent work from the following.  When preparing for lecture classes, students need to:  before the next lecture, it is necessary to review the summary of the material of the previous Lectures. If you have difficulties in perceiving the material, you should refer to the main literary sources. If it was not possible to understand the material again, then contact the lecturer (according to the schedule of his consultations) or the teacher in practical classes.  Practical classes complete the study of the most important topics of the discipline. They serve to consolidate the studied material, develop the skills and abilities of preparing reports, messages, gaining experience in oral public speeches, conducting discussions, argumentation and defending the propositions put forward, as well as to monitor the degree of readiness of students in the discipline being studied by the teacher.  When preparing for a practical lesson, students have the opportunity to use the advice of a teacher.  When preparing for practical classes, students need to:  bring with you the literature recommended by the teacher for a specific lesson;  before the next practical lesson on the recommended literary sources, work out the theoretical material corresponding to the topic of the lesson;  at the beginning of classes, ask the teacher questions about the material that caused difficulties in understanding and mastering it when solving tasks set for independent solution;  during the seminar, give specific, clear answers to the substance of the questions;  at the training session, bring each task to the final solution, demonstrate an understanding of the calculations (analyses, situations), in case of difficulties, contact the teacher.  Students who have missed classes (regardless of the reasons), who do not have a written solution to problems or are not prepared for this practical lesson, are recommended to come to the teacher’s consultation no later than 2 weeks and report on the topic studied in the lesson.  The methodological guidelines necessary for studying and passing the discipline are given as part of the educational program. | | |
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| **6.6. METHODOLOGICAL RECOMMENDATIONS FOR THE TRAINING OF PERSONS WITH LIMITED HEALTH OPPORTUNITIES AND THE DISABLED** | | |
| The development of the discipline by students with disabilities can be organized both jointly with other students and in separate groups. Special conditions are assumed for students with disabilities to receive education.  The teaching staff gets acquainted with the psychological and physiological characteristics of students with disabilities and persons with disabilities, individual rehabilitation programs for the disabled (if available). If necessary, additional teaching support is provided by tutors, psychologists, social workers, trained assistants.  In accordance with the methodological recommendations of the Ministry of Education and Science of the Russian Federation (approved April 8, 2014 N AK-44/05vn), the course is supposed to use socially active and reflective teaching methods, technologies of socio-cultural rehabilitation in order to assist in establishing full-fledged interpersonal relationships with other students, creating a comfortable psychological climate in the student group. Selection and development of educational materials are made taking into account the provision of material in various forms: auditory, visual, using special technical means and information systems.  Mediamaterials should also be used and adapted taking into account the individual characteristics of the training of persons with disabilities.  The development of the discipline by persons with disabilities is carried out using general and special purpose teaching tools (personal and collective use). Material and technical support provides for the adaptation of classrooms to the needs of persons with disabilities. | | |

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| The form of certification for students with disabilities is established taking into account individual psychophysical characteristics. For students with HIA, an accessible form of assignment of assessment tools is provided, namely:  - in printed or electronic form (for persons with disorders of the musculoskeletal system);  - in printed or electronic form with enlarged font and contrast (for persons with hearing, speech, vision impairments);  - reading the task aloud by the assistant (for visually impaired persons).  Students with disabilities have increased time to prepare answers to control questions. For such students, an accessible form of providing answers to tasks is provided, namely:  - written on paper or a set of answers on a computer (for persons with hearing and speech impairments);  - choosing an answer from possible options using the services of an assistant (for people with musculoskeletal disorders);  - oral interview (for persons with visual impairments, musculoskeletal system).  If necessary, for students with disabilities, the procedure for evaluating learning outcomes can be carried out in several stages. |

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| Federal State Budget Educational Institution of Higher Education  «MIREA – Russian Technological University» | | | | | | | | | | | | | | | | | | | | | |
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| Working program of the discipline (module) | | | | | | | | | | | | | | | | | | | | | |
| **Business process modeling** | | | | | | | | | | | | | | | | | | | | | |
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|  | Direction of training | | | | | | |  | **11.04.04 Electronics and nanoelectronics** | | | | | | | | | | | | |
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|  | Profile | | | | | | |  | **Engineering of modern materials for information technology, renewable energy and sensing** | | | | | | | | | | | | |
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|  | Qualification | | | | |  |  |  | **Master** | | | | | | | | | | | | |
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|  | Form of education | | | | |  |  |  | **Full-time** | | | | | | | | | |  |  |  |
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| **Distribution of discipline hours and forms of intermediate certification by semesters** | | | | | | | | | | | | | | | | | | | | | |
| Semester | | Credits | Distribution of hours | | | | | | | | | | | | | | | Forms of intermediate attestation | | |  |
| Total | Lectures | | | | Laboratory work | | | Practical classes | Independent work of students | | Contact work during practice and (or) certification | | | Control of training |  |
| 3 | | 1 | 36 | 8 | | | | 0 | | | 8 | 11 | | 0,25 | | | 8,75 | Test | | |  |
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| The program was made by: |  |  |  |  |
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| *Associate Professor, A. Vartanyan \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_* | | | | |
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| Working program of the discipline | | |  |  |
| **Business process modeling** | | | | |
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| it is developed in accordance with FSES HE: | | |  |  |
| Federal State Educational Standard of Higher Education - Magistracy in the Direction of training 11.04.04 Electronics and nanoelectronics (order of the Ministry of Science and Higher Education of the Russian Federation from 22.09.2017. № 959) | | | | |
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| it is based on the curriculum: | | |  |  |
| Direction of training: 11.04.04 Electronics and nanoelectronics  Profile: «Engineering of modern materials for information technology, renewable energy and sensing» | | | | |
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| The working program was approved at the meeting of the department | | | | |
| **Department of Information Technologies in Public Administration** | | | | |
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| Minutes of meeting from 31.05.2020 № 1  Head of the Department A. Soroko \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ | | | | |

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| **Approval of the WPD for execution in the next academic year** | | | | |
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| The working program was revised, discussed and approved for execution in the 2021-2022 academic year at a meeting of the department | | | | |
| **Department of Information Technologies in Public Administration** | | | | |
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|  | Minutes of meeting from \_\_ \_\_\_\_\_\_\_\_\_\_ 2021. № \_\_  Head of the Department \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ | | | |
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| **Approval of the WPD for execution in the next academic year** | | | | |
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| The working program was revised, discussed and approved for execution in the 2022-2023 academic year at a meeting of the department | | | | |
| **Department of Information Technologies in Public Administration** | | | | |
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|  | Minutes of meeting from \_\_ \_\_\_\_\_\_\_\_\_\_ 2022. № \_\_  Head of the Department \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ | | | |
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| **Approval of the WPD for execution in the next academic year** | | | | |
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| The working program was revised, discussed and approved for execution in the 2023-2024 academic year at a meeting of the department | | | | |
| **Department of Information Technologies in Public Administration** | | | | |
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|  | Minutes of meeting from \_\_ \_\_\_\_\_\_\_\_\_\_ 2023. № \_\_  Head of the Department \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ | | | |
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| **Approval of the WPD for execution in the next academic year** | | | | |
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| The working program was revised, discussed and approved for execution in the 2024-2025 academic year at a meeting of the department | | | | |
| **Department of Information Technologies in Public Administration** | | | | |
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|  | Minutes of meeting from \_\_ \_\_\_\_\_\_\_\_\_\_ 2024. № \_\_  Head of the Department \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ | | | |
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| **1. OBJECTIVES OF MASTERING THE DISCIPLINE (MODULE)** | | | | | |
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| The discipline «Business process modeling» aims to contribute to the formation of students’ competencies, provided by this work program in accordance with the requirements of FSES HE in the direction of training 11.04.04 Electronics and nanoelectronics, taking into account the specifics of the profile – «Engineering of modern materials for information technology, renewable energy and sensing». | | | | | |
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| **2. PLACE OF DISCIPLINE (MODULE) IN THE STRUCTURE OF THE EDUCATIONAL PROGRAM** | | | | | |
|  | Direction of training: |  | 11.04.04 Electronics and nanoelectronics | | |
|  |
|  | Profile: |  | Engineering of modern materials for information technology, renewable energy and sensing | | |
|  |  |  |
|  | Block: |  | <could not determine> | | |
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|  | Part: |  | Electives | | |
|  |  |  |
|  | Total labor intensity: |  | 1 credit (36 academic hours). | | |
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| **3. THE STUDENT’S COMPETENCIES FORMED AS A RESULT OF MASTERING THE DISCIPLINE (MODULE)** | | | | | |
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| As a result of mastering the practice, the student must master the following competencies: | | | | | |
| **UC-2** - Capable to manage a project at all stages of its life cycle | | | | | |
| **UC-3** - Capable to organize and lead the work of the team, developing team strategy to achieve this goal | | | | | |
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| **PLANNED RESULTS OF TRAINING IN THE DISCIPLINE (MODULE), CHARACTERIZING THE FORMATION OF COMPETENCIES** | | | | | |
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| **UC-2 : Capable to manage a project at all stages of its life cycle** | | | | | |
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| **UC-2.1: Forms a project task based on the problem posed, the way to solve it through the implementation of project management** | | | | | |
| **To know:** | | | | | |
| - Principles of project management based on business process modeling | | | | | |
| **Be able to:** | | | | | |
| - To form a project task based on business process modeling | | | | | |
| **Possess:** | | | | | |
| - Methods of forming project tasks based on business process modeling | | | | | |
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| **UC-2.2: Develops a project concept within the framework of the designated problem and a project implementation plan, taking into account possible implementation risks and opportunities to eliminate them** | | | | | |
| **To know:** | | | | | |
| - Typical project concepts and theoretical foundations of implementation planning | | | | | |
| **Be able to:** | | | | | |
| - Develop project concepts and project implementation plans | | | | | |
| **Possess:** | | | | | |
| - Methods of developing project concepts and project implementation plans | | | | | |
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| **UC-3 : Capable to organize and lead the work of the team, developing team strategy to achieve this goal** | | | | | |

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| **UC-3.1: Develops strategy of teamwork and on its basis organizes the selection of team members to achieve the goal** | | | | | | |
| **To know:** | | | | | | |
| - Principles of teamwork organization | | | | | | |
| **Be able to:** | | | | | | |
| - Organize and manage the work of the team | | | | | | |
| **Possess:** | | | | | | |
| - Methods of modeling business processes, taking into account the need to organize teamwork | | | | | | |
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| **UC-3.2: Organizes and modifies the work of the team, including on the basis of collegial decisions** | | | | | | |
| **To know:** | | | | | | |
| - Principles of organization and adjustment of teamwork | | | | | | |
| **Be able to:** | | | | | | |
| - Organize, manage and adjust the work of the team | | | | | | |
| **Possess:** | | | | | | |
| - Methods of modeling business processes, taking into account the need to organize teamwork | | | | | | |
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| **AS A RESULT OF STUDYING THE DISCIPLINE (MODULE), THE STUDENT MUST** | | | | | | |
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| **To know:** | | | | | | |
| - Typical project concepts and theoretical foundations of implementation planning | | | | | | |
| - Principles of organization and adjustment of teamwork | | | | | | |
| - Principles of teamwork organization | | | | | | |
| - Principles of project management based on business process modeling | | | | | | |
| **Be able to:** | | | | | | |
| - Organize and manage the work of the team | | | | | | |
| - Develop project concepts and project implementation plans | | | | | | |
| - Organize, manage and adjust the work of the team | | | | | | |
| - To form a project task based on business process modeling | | | | | | |
| **Possess:** | | | | | | |
| - Methods of modeling business processes, taking into account the need to organize teamwork | | | | | | |
| - Methods of forming project tasks based on business process modeling | | | | | | |
| - Methods of developing project concepts and project implementation plans | | | | | | |
| - Methods of modeling business processes, taking into account the need to organize teamwork | | | | | | |
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| **4. STRUCTURE AND CONTENT OF THE DISCIPLINE (MODULE)** | | | | | | |
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| During the training sessions, the organization ensures the development of students’ teamwork skills, interpersonal communication, decision-making and leadership qualities. | | | | | | |
| **Code** | **Name of sections and topics /type of classes/** | | **Semester** | **Academic Hours** | **Competencies** | |
| **1. Functional and process approaches to organization management** | | | | | | |

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| **1.1** | **Reasons for failures of modeling projects and business process reorganization** **(Lec).** Reasons for project failures. Levels of development of the business process reengineering project. The composition of the stages of a typical project of modeling and reorganization of business processes of the organization. | 3 | 1 | UC-2.1, UC- 2.2, UC-3.1, UC-3.2 |
| **1.2** | **Performing practical tasks (Pr).** Functional and cost modeling. Discussion of the topic "Methodology for describing business processes". | 3 | 1 | UC-2.1, UC- 2.2, UC-3.1, UC-3.2 |
| **1.3** | **Preparation for classroom classes (IWS).** | 3 | 1 | UC-2.1, UC- 2.2, UC-3.1, UC-3.2 |
| **2. Theoretical foundations of process management** | | | | |
| **2.1** | **Theoretical foundations of process management (Lec).** Management cycles. The concept of Business Process Management. | 3 | 1 | UC-2.1, UC- 2.2, UC-3.1, UC-3.2 |
| **2.2** | **Performing practical tasks (Pr).** Functional-cost modeling. | 3 | 1 | UC-2.1, UC- 2.2, UC-3.1, UC-3.2 |
| **2.3** | **Preparation for classroom classes (IWS).** | 3 | 1 | UC-2.1, UC- 2.2, UC-3.1, UC-3.2 |
| **3. Processes and their components** | | | | |
| **3.1** | **Processes and their components (Lec).** The concept of process and business process. Classification of processes. Organization as a set of processes. Consumers of business modeling results. | 3 | 1 | UC-2.1, UC- 2.2, UC-3.1, UC-3.2 |
| **3.2** | **Performing practical tasks (Pr).** Discussion of the topic "Processes and their components". | 3 | 1 | UC-2.1, UC- 2.2, UC-3.1, UC-3.2 |
| **3.3** | **Preparation for classroom classes (IWS).** | 3 | 1 | UC-2.1, UC- 2.2, UC-3.1, UC-3.2 |
| **4. Methodology for describing business processes** | | | | |
| **4.1** | **Methodology for describing business processes (Lec).** The concept of methodology for describing business processes. Types of business process models. The history of the development of approaches to quality management. | 3 | 1 | UC-2.1, UC- 2.2, UC-3.1, UC-3.2 |
| **4.2** | **Performing practical tasks (Pr).** Introduction to the IDEF0 notation. Working with functional blocks. | 3 | 1 | UC-2.1, UC- 2.2, UC-3.1, UC-3.2 |
| **4.3** | **Preparation for classroom classes (IWS).** | 3 | 1 | UC-2.1, UC- 2.2, UC-3.1, UC-3.2 |
| **5. Reasons for failures of modeling projects and business process reorganization** | | | | |
| **5.1** | **Performing practical tasks (Pr).** Discussion of the topic "Functional and process approaches to organization management". | 3 | 1 | UC-2.1, UC- 2.2, UC-3.1, UC-3.2 |

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| **5.2** | **Preparation for classroom classes (IWS).** | | 3 | 2 | UC-2.1, UC- 2.2, UC-3.1, UC-3.2 | |
| **5.3** | **Functional and process approaches to organization management (Lec).** Functional management. A functionally-oriented organization. Business evolution. Process approach. | | 3 | 1 | UC-2.1, UC- 2.2, UC-3.1, UC-3.2 | |
| **6. Setting goals for describing business processes** | | | | | | |
| **6.1** | **Setting goals for describing business processes (Lec).** Formulation of the project objectives. Methodology for structuring project goals. Methodology for determining project goals based on existing problems. | | 3 | 1 | UC-2.1, UC- 2.2, UC-3.1, UC-3.2 | |
| **6.2** | **Performing practical tasks (Pr).** Creating a context diagram and decomposition diagrams. | | 3 | 1 | UC-2.1, UC- 2.2, UC-3.1, UC-3.2 | |
| **6.3** | **Preparation for classroom classes (IWS).** | | 3 | 1 | UC-2.1, UC- 2.2, UC-3.1, UC-3.2 | |
| **7. Choosing a methodology for describing the organization's business processes** | | | | | | |
| **7.1** | **Choosing a methodology for describing the organization's business processes (Lec).** Methodology of accelerated description of business processes. Methodology for the complete description of business processes. Comparative analysis of approaches: advantages and disadvantages. | | 3 | 1 | UC-2.1, UC- 2.2, UC-3.1, UC-3.2 | |
| **7.2** | **Performing practical tasks (Pr).** Discussion of the topic "Theoretical foundations of process management". | | 3 | 1 | UC-2.1, UC- 2.2, UC-3.1, UC-3.2 | |
| **7.3** | **Preparation for classroom classes (IWS).** | | 3 | 2 | UC-2.1, UC- 2.2, UC-3.1, UC-3.2 | |
| **8. Preparation of a draft description of business processes** | | | | | | |
| **8.1** | **Preparation of a draft description of business processes (Lec).** The scope of work on the preparation of the project. The roles of employees in the project. Errors in the implementation of the preparatory stage of the project. | | 3 | 1 | UC-2.1, UC- 2.2, UC-3.1, UC-3.2 | |
| **8.2** | **Performing practical tasks (Pr).** Creating a "Node Tree" diagram and an "Exposure-only" diagram. | | 3 | 1 | UC-2.1, UC- 2.2, UC-3.1, UC-3.2 | |
| **8.3** | **Preparation for classroom classes (IWS).** | | 3 | 2 | UC-2.1, UC- 2.2, UC-3.1, UC-3.2 | |
| **9. Intermediate certification (Test)** | | | | | | |
| **9.1** | **Preparation for the intermediate certification (Test).** | | 3 | 8,75 | UC-2.1, UC- 2.2, UC-3.1, UC-3.2 | |
| **9.2** | **Contact work with the teacher during the intermediate certification (CWC).** | | 3 | 0,25 | UC-2.1, UC- 2.2, UC-3.1, UC-3.2 | |
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| **5. EVALUATION MATERIALS** | | | | | | |

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| **5.1. List of competencies** | | |
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| List of competencies, the development of which the study of the discipline is aimed at «Business process modeling», with an indication of the results of their formation in the process of mastering the educational program, presented in paragraph 3 of this work program | | |
| **5.2. Typical control questions and tasks** | | |
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| 1. "The phenomenon of working with coolness" and the principles of F.W. Taylor's management.  2. SWOT analysis of the process. Process analysis in relation to standard requirements.  3. Analysis of process problems: identification of problem areas. Ranking of processes based on subjective evaluation.  4. Important aspects of the management of the working group on business process modeling.  5. Visual analysis of graphical diagrams of the process.  6. Groups of process outputs.  7. Management tasks in the business process modeling project.  8. History of development of business process modeling methodologies.  9. Classification of types of business process analysis.  10. Classification of process indicators.  11. Classification of consumers of business modeling results.  12. Classification of processes in relation to customers. Classification of processes in relation to obtaining added value.  13. Classification of processes. Classification of processes by the level of detail of consideration.  14. The concept of the "achieving worker" by F.W. Taylor.  15. The concept of the "achieving leader" by F.W. Taylor.  16. Indirect assessment of customer satisfaction.  17. International Financial Reporting Standards.  18. ABC cost analysis methodology.  19. Methods used in the decomposition of processes. Features of the work on the organization of information collection.  20. Interview techniques. General rules for conducting interviews.  21. Shortcomings of the methodology for determining project goals based on existing problems.  22. Shortcomings of the methodology of a complete description of business processes.  23. Shortcomings of the methodology of accelerated description of the business processes of the organization.  24. Conditions are necessary for the success of business process reorganization projects.  25. General requirements for information about the progress of the process.  26. Definition of "methodology for describing business processes". Components of the methodology.  27. Definition of "Business process modeling". Types of business process models.  28. The basic principle of business analysis. Subordination of processes to strategy.  29. The main ideas of F.W. Taylor — "Scientific approach to management" (Scientific Management).  30. Features of checking the adequacy of detailed processes. Typical errors in the performance of work on a detailed description of business processes.  31. Errors in the implementation of the preparatory stage of the project.  32. List of information collection activities in the divisions.  33. Performance indicators and cost indicators.  34. Product indicators.  35. Process performance indicators.  36. The concept of "5M" and its development.  37. The concept of "Business Process Management". Business Process Management building.  38. The concept of "process owner". How to decide on the appointment of the owner of the process?  39. The concept of "process". Evolution of business organization.  40. The concept of "process-oriented organization". The "supplier/consumer" model.  41. The concept of "process regulations". Information contained in the rules of procedure. | | |

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| 42. The concept of "functionally-oriented organization". Features of a functionally-oriented organization.  43. Concepts and characteristics of inputs and resources of the process.  44. The sequence of work performed at the preparatory stage of the project.  45. Information flows of functional hierarchy links.  46. Rules for the development and approval of documentation.  47. Rules for the approval and implementation of documentation.  48. Rules for the formation of schemes of top-level business process models. The main groups of functions of top-level processes.  49. Presentation of information about the progress of the process.  50. Principles of A. Fayol's management.  51. Reasons for project failures. To characterize the problem of incorrect setting of project goals.  52. Reasons for project failures. To characterize the problem of the absence of a team of top-level managers.  53. Problem’s characteristic of the functional structure.  54. The procedure for monitoring the compliance of the finished product with the requirements of the specification.  55. The roles of the participants of the working group on business process modeling.  56. The scope of work on the preparation of the project.  57. Comparison of existing methodologies for describing business processes by the completeness of the description of processes, the degree of participation of the organization's personnel in the project and the complexity of the project.  58. Comparison of existing methodologies for describing business processes according to the subjectivity of describing processes, the degree of risk of project failure and the possibility of using project results.  59. The degree of detail of the description of the process.  60. The scheme of interrelations of methodologies for describing business processes.  61. The scheme of the owner-controlled process.  62. A. Fayol's theory of administration.  63. Technical indicators and quality indicators.  64. Types of inconsistencies when checking the correctness of process models. The structure of the business process modeling report.  65. Requirements for the quality of information used for making managerial decisions.  66. Requirements for reviewers of business process models. The reaction of reviewers when checking the adequacy of models.  67. Levels of development of the business process reengineering project.  68. Objectives of the description of top-level business processes.  69. Objectives of projects for modeling organizational processes  70. The author-reader cycle.  71. Taylor and Ishikawa cycles.  72. The Schuhart-Deming and Harry and Schroeder cycles.  73. Steps of the methodology for a complete description of business processes.  74. Steps of the methodology of accelerated description of business processes.  75. Stages of the life cycle of process management.  76. The stages of the methodology for determining the objectives of the project based on existing problems.  77. Stages of the methodology for structuring the project goals.  78. Stages of the methodology for forming schemes of detailed description of processes. Types of inconsistencies between the created detailed processes.  79. Stages of a typical business process reorganization project. Give a description of the third and fourth stages.  80. Stages of a typical business process reorganization project. Give a description of the first and second stages. |
| **5.3. Fund of evaluation Materials** |

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| A complete list of evaluation materials is provided in the Appendix 1. | | | | | |
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| **6. MATERIAL, TECHNICAL, EDUCATIONAL AND METHODOLOGICAL SUPPORT OF THE DISCIPLINE (MODULE)** | | | | | |
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| **6.1. MATERIAL AND TECHNICAL SUPPORT OF THE DISCIPLINE (МОДУЛЯ)** | | | | | |
| **Name of premises** | | | | **List of main equipment** | |
| Computer classroom | | | | Computer equipment with the ability to connect to the Internet, multimedia equipment, specialized furniture. | |
| Classroom for lectures and seminars, group and individual consultations, ongoing monitoring and intermediate certification | | | | Multimedia equipment, specialized furniture, sets of demonstration equipment and educational and visual aids that provide thematic illustrations. | |
| A room for independent work of students | | | | Computer equipment with the ability to connect to the Internet and provide access to the electronic information and educational environment of the organization. | |
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| **6.2. LIST OF SOFTWARE** | | | | | |
| 1. |  | Microsoft Windows. Contract No. 32009183466 from 02.07.2021. | | | |
| 2. |  | Microsoft Office. Contract No. 32009183466 from 02.07.2021. | | | |
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| **6.3. RECOMMENDED LITERATURE** | | | | | |
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| **6.3.1. Basic literature** | | | | | |
| 1. |  | Chikurov N. G. Modelirovanie sistem i processov:Dop. UMO vuzov v kach. ucheb. posobiya dlya vuzov. - M.: RIOR: INFRA-M, 2013. - 397 s. | | | |
| 2. |  | Golubeva N. V. Matematicheskoe modelirovanie sistem i processov [Electronic resource]:. - Sankt-Peterburg: Lan', 2016. - 192 s. – Access mode: https://e.lanbook.com/books/element.php?pl1\_id=76825 | | | |
| 3. |  | Hudyakova E. V., Bondarenko A. M., Kachanova L. S., Kushnaryova M. N., Gorbachev M. I. Business process modeling na predpriyatiyah APK [Electronic resource]:uchebnik dlya vo. - Sankt-Peterburg: Lan', 2020. - 172 s. – Access mode: https://e.lanbook.com/book/143702 | | | |
| 4. |  | Koshkin D. E., Moroz YU. V., SHemonchuk D. S. Business process modeling [Electronic resource]:praktikum dlya studentov, obuchayushchihsya po napravleniyam podgotovki 38.03.04 i 38.03.05 (pervaya chast'). - M.: RTU MIREA, 2018. -– Access mode: http://library.mirea.ru/secret/06032019/1937.iso | | | |
| 5. |  | Esaulov M. N., Esaulov N. P., Kalushin S. V., i dr. Upravlenie processami:uchebnoe posobie. - M.: MIREA, 2015. - 115 s. | | | |
| 6. |  | Repin V. V., Eliferov V. G. Processnyj podhod k upravleniyu. Modelirovanie biznes- processov:. - M.: RIA "Standarty i kachestvo", 2004. - 404 s. | | | |
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| **6.4. RECOMMENDED LIST OF MODERN PROFESSIONAL DATABASES AND INFORMATION REFERENCE SYSTEMS** | | | | | |
| 1. |  | Consultant Plus http:// www.consultant.ru | | | |
| 2. |  | Information and legal portal GARANT http:// www.garant.ru | | | |
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| **6.5. METHODICAL INSTRUCTIONS FOR STUDENTS STUDYING THE DISCIPLINE (MODULE)** | | | | | |
| The student’s independent work is aimed at preparing for academic classes and at developing knowledge, skills and abilities provided for in the discipline program. | | | | | |

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| In accordance with the curriculum, the discipline may include Lectures, practical classes and Laboratory work, as well as the execution and defense of a course project (work). Successful study of the discipline requires attending all types of classes, completing teacher assignments and familiarization with basic and additional literature. Depending on the activities provided for in the curriculum and section 4 of this program, the student chooses methodological guidelines for independent work from the ones listed below.  When preparing for lecture classes, students need to:  before the next lecture, it is necessary to review the summary of the material of the previous Lectures. If you have difficulties in perceiving the material, you should refer to the main literary sources. If it was not possible to understand the material again, then contact the lecturer (according to the schedule of his consultations) or the teacher in practical classes.  Practical classes complete the study of the most important topics of the discipline. They serve to consolidate the studied material, develop the skills and abilities of preparing reports, messages, gaining experience in oral public speeches, conducting discussions, argumentation and defending the propositions put forward, as well as to monitor the degree of readiness of students in the discipline being studied by the teacher.  When preparing for a practical lesson, students have the opportunity to use the advice of a teacher.  When preparing for practical classes, students need to:  bring with you the literature recommended by the teacher for a specific lesson;  before the next practical lesson on the recommended literary sources, work out the theoretical material corresponding to the topic of the lesson;  at the beginning of classes, ask the teacher questions about the material that caused difficulties in understanding and mastering it when solving tasks set for independent solution;  during the seminar, give specific, clear answers to the substance of the questions;  at the training session, bring each task to the final solution, demonstrate an understanding of the calculations (analyses, situations), in case of difficulties, contact the teacher.  Students who have missed classes (regardless of the reasons), who do not have a written solution to problems or are not prepared for this practical lesson, are recommended to come to the teacher’s consultation no later than 2 weeks and report on the topic studied in the lesson.  The methodological guidelines necessary for studying and passing the discipline are given as part of the educational program. | | |
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| **6.6. METHODOLOGICAL RECOMMENDATIONS FOR THE TRAINING OF PERSONS WITH LIMITED HEALTH OPPORTUNITIES AND THE DISABLED** | | |
| The development of the discipline by students with disabilities can be organized both jointly with other students and in separate groups. Special conditions are assumed for students with disabilities to receive education.  The teaching staff gets acquainted with the psychological and physiological characteristics of students with disabilities and persons with disabilities, individual rehabilitation programs for the disabled (if available). If necessary, additional teaching support is provided by tutors, psychologists, social workers, trained assistants.  In accordance with the methodological recommendations of the Ministry of Education and Science of the Russian Federation (approved April 8, 2014 N AK-44/05vn), the course is supposed to use socially active and reflective teaching methods, technologies of socio-cultural rehabilitation in order to assist in establishing full-fledged interpersonal relationships with other students, creating a comfortable psychological climate in the student group. Selection and development of educational materials are made taking into account the provision of material in various forms: auditory, visual, using special technical means and information systems. | | |

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| Mediamaterials should also be used and adapted taking into account the individual characteristics of the training of persons with disabilities.  The development of the discipline by persons with disabilities is carried out using general and special purpose teaching tools (personal and collective use). Material and technical support provides for the adaptation of classrooms to the needs of persons with disabilities.  The form of certification for students with disabilities is established taking into account individual psychophysical characteristics. For students with HIA, an accessible form of assignment of assessment tools is provided, namely:  - in printed or electronic form (for persons with disorders of the musculoskeletal system);  - in printed or electronic form with enlarged font and contrast (for persons with hearing, speech, vision impairments);  - reading the task aloud by the assistant (for visually impaired persons).  Students with disabilities have increased time to prepare answers to control questions. For such students, an accessible form of providing answers to tasks is provided, namely:  - written on paper or a set of answers on a computer (for persons with hearing and speech impairments);  - choosing an answer from possible options using the services of an assistant (for people with musculoskeletal disorders);  - oral interview (for persons with visual impairments, musculoskeletal system).  If necessary, for students with disabilities, the procedure for evaluating learning outcomes can be carried out in several stages. |

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| MINISTRY OF SCIENCE AND HIGHER EDUCATION OF THE RUSSIAN FEDERATION | | | | | | | | | | | | | | | | | | | | | |
| Federal State Budget Educational Institution of Higher Education  «MIREA – Russian Technological University» | | | | | | | | | | | | | | | | | | | | | |
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| **Institute of Physics and Technology** | | | | | | | | | | | | | | | | | | | | | |
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| Working program of the discipline (module) | | | | | | | | | | | | | | | | | | | | | |
| **Simulation using COMSOL Multiphysics** | | | | | | | | | | | | | | | | | | | | | |
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|  | Department leading the training | | | | | |  |  | **Department of Nanoelectronics** | | | | | | | | | | | | |
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|  | Direction of training | | | | | | |  | **11.04.04 Electronics and nanoelectronics** | | | | | | | | | | | | |
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|  | Profile | | | | | | |  | **Engineering of modern materials for information technology, renewable energy and sensing** | | | | | | | | | | | | |
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|  | Qualification | | | | |  |  |  | **Master** | | | | | | | | | | | | |
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|  | Form of education | | | | |  |  |  | **Full-time** | | | | | | | | | |  |  |  |
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|  | Total labor intensity | | | |  |  |  |  | **6 credits** | | | | | | | | | |  |  |  |
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| **Distribution of discipline hours and forms of intermediate certification by semesters** | | | | | | | | | | | | | | | | | | | | | |
| Semester | | Credits | Distribution of hours | | | | | | | | | | | | | | | Forms of intermediate attestation | | |  |
| Total | Lectures | | | | Laboratory work | | | Practical classes | Independent work of students | | Contact work during practice and (or) certification | | | Control of training |  |
| 2 | | 6 | 216 | 16 | | | | 0 | | | 64 | 82 | | 4,35 | | | 49,65 | Exam, Coursework | | |  |
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| The program was made by: |  |  |  |  |
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| *Ph.D. Physics and Mathematics, Senior lecturer, A. Buryakov \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_* | | | | |
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| Working program of the discipline | | |  |  |
| **Simulation using COMSOL Multiphysics** | | | | |
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| it is developed in accordance with FSES HE: | | |  |  |
| Federal State Educational Standard of Higher Education - Magistracy in the Direction of training 11.04.04 Electronics and nanoelectronics (order of the Ministry of Science and Higher Education of the Russian Federation from 22.09.2017. № 959) | | | | |
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| it is based on the curriculum: | | |  |  |
| Direction of training: 11.04.04 Electronics and nanoelectronics  Profile: «Engineering of modern materials for information technology, renewable energy and sensing» | | | | |
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| The working program was approved at the meeting of the department | | | | |
| **Department of Nanoelectronics** | | | | |
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| Minutes of meeting from 02.03.2021 № 3  Head of the Department A. Sigov \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ | | | | |

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| **Approval of the WPD for execution in the next academic year** | | | | |
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| The working program was revised, discussed and approved for execution in the 2022-2023 academic year at a meeting of the department | | | | |
| **Department of Nanoelectronics** | | | | |
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|  | Minutes of meeting from \_\_ \_\_\_\_\_\_\_\_\_\_ 2022. № \_\_  Head of the Department \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ | | | |
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| **Approval of the WPD for execution in the next academic year** | | | | |
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| The working program was revised, discussed and approved for execution in the 2023-2024 academic year at a meeting of the department | | | | |
| **Department of Nanoelectronics** | | | | |
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|  | Minutes of meeting from \_\_ \_\_\_\_\_\_\_\_\_\_ 2023. № \_\_  Head of the Department \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ | | | |
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| **Approval of the WPD for execution in the next academic year** | | | | |
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| The working program was revised, discussed and approved for execution in the 2024-2025 academic year at a meeting of the department | | | | |
| **Department of Nanoelectronics** | | | | |
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|  | Minutes of meeting from \_\_ \_\_\_\_\_\_\_\_\_\_ 2024. № \_\_  Head of the Department \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ | | | |
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| **Approval of the WPD for execution in the next academic year** | | | | |
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| The working program was revised, discussed and approved for execution in the 2025-2026 academic year at a meeting of the department | | | | |
| **Department of Nanoelectronics** | | | | |
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|  | Minutes of meeting from \_\_ \_\_\_\_\_\_\_\_\_\_ 2025. № \_\_  Head of the Department \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ | | | |
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| **1. OBJECTIVES OF MASTERING THE DISCIPLINE (MODULE)** | | | | | |
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| The discipline «Simulation using COMSOL Multiphysics» aims to contribute to the formation of students’ competencies, provided by this work program in accordance with the requirements of FSES HE in the direction of training 11.04.04 Electronics and nanoelectronics, taking into account the specifics of the profile – «Engineering of modern materials for information technology, renewable energy and sensing». | | | | | |
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| **2. PLACE OF DISCIPLINE (MODULE) IN THE STRUCTURE OF THE EDUCATIONAL PROGRAM** | | | | | |
|  | Direction of training: |  | 11.04.04 Electronics and nanoelectronics | | |
|  |
|  | Profile: |  | Engineering of modern materials for information technology, renewable energy and sensing | | |
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|  | Block: |  | Disciplines (modules) | | |
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|  | Part: |  | Part of the curriculum formed by the participants of educational | | |
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|  | Total labor intensity: |  | 6 credits (216 academic hours). | | |
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| **3. THE STUDENT’S COMPETENCIES FORMED AS A RESULT OF MASTERING THE DISCIPLINE (MODULE)** | | | | | |
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| As a result of mastering the practice, the student must master the following competencies: | | | | | |
| **PC-3** - Capable of determining possible physical implementation options, physical and mathematical models of micro- and nanosystems and using software tools for their design and modeling | | | | | |
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| **PLANNED RESULTS OF TRAINING IN THE DISCIPLINE (MODULE), CHARACTERIZING THE FORMATION OF COMPETENCIES** | | | | | |
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| **PC-3 : Capable of determining possible physical implementation options, physical and mathematical models of micro- and nanosystems and using software tools for their design and modeling** | | | | | |
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| **PC-3.1: Defines possible variants of physical and mathematical models in the field of nanoelectronics** | | | | | |
| **To know:** | | | | | |
| - the main features of the COMSOL Multiphysics analytical computing package for solving problems related to modeling physical processes in the study of nanoelectronics elements. | | | | | |
| **Be able to:** | | | | | |
| - use modern automation tools, apply theoretical knowledge in practice using the analytical capabilities of the COMSOL package, simulate and solve various tasks of operations research using the COMSOL package | | | | | |
| **Possess:** | | | | | |
| - Modern software tools for the preparation of design and technological documentation, conceptual apparatus and modern computational methods of operations research | | | | | |
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| **PC-3.2: Uses software tools for designing and modeling electronics elements** | | | | | |
| **To know:** | | | | | |

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| - effective methods of designing and modeling parameters and characteristics of devices, circuits and devices of micro- and nanoelectronics for various functional purposes | | | | | | |
| **Be able to:** | | | | | | |
| - apply in practice methods and tools of computer-aided design and modeling of micro- and nanosystems | | | | | | |
| **Possess:** | | | | | | |
| - methods and tools of specialized computer-aided design and modeling of micro- and nanosystems | | | | | | |
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| **AS A RESULT OF STUDYING THE DISCIPLINE (MODULE), THE STUDENT MUST** | | | | | | |
| **To know:** | | | | | | |
| - effective methods of designing and modeling parameters and characteristics of devices, circuits and devices of micro- and nanoelectronics for various functional purposes | | | | | | |
| - the main features of the COMSOL Multiphysics analytical computing package for solving problems related to modeling physical processes in the study of nanoelectronics elements. | | | | | | |
| **Be able to:** | | | | | | |
| - apply in practice methods and tools of computer-aided design and modeling of micro- and nanosystems | | | | | | |
| - use modern automation tools, apply theoretical knowledge in practice using the analytical capabilities of the COMSOL package, simulate and solve various tasks of operations research using the COMSOL package | | | | | | |
| **Possess:** | | | | | | |
| - methods and tools of specialized computer-aided design and modeling of micro- and nanosystems | | | | | | |
| - Modern software tools for the preparation of design and technological documentation, conceptual apparatus and modern computational methods of operations research | | | | | | |
| **4. STRUCTURE AND CONTENT OF THE DISCIPLINE (MODULE)** | | | | | | |
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| During the training sessions, the organization ensures the development of students’ teamwork skills, interpersonal communication, decision-making and leadership qualities. | | | | | | |
| **Code** | **Name of sections and topics /type of classes/** | | **Semester** | **Academic Hours** | **Competencies** | |
| **1. Simulation using COMSOL Multiphysics** | | | | | | |
| **1.1** | **Lecture** **1.** **Introduction to computer modeling. (Lec).** Getting started with COMSOL Multiphysics. Physical interfaces. The working window of the program. The main stages of the work. | | 2 | 2 | PC-3.1, PC-3.2 | |
| **1.2** | **Lecture** **2.** **Introduction to COMSOL Multiphysics.** **(Lec).** Getting Started at COMSOL Multiphysics | | 2 | 2 | PC-3.1, PC-3.2 | |
| **1.3** | **Lecture** **3.** **Modeling of heat transfer processes. (Lec).** Modeling of heat transfer processes. | | 2 | 2 | PC-3.1, PC-3.2 | |
| **1.4** | **Lecture** **4.** **Modeling of heat transfer processes caused by resistive (Joule) heating. (Lec).** Modeling of heat transfer processes caused by resistive (Joule) heating. | | 2 | 2 | PC-3.1, PC-3.2 | |

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| **1.5** | **Lecture** **5.** **Modeling of deformations. (Lec).** Modeling of deformations. | 2 | 2 | PC-3.1, PC-3.2 |
| **1.6** | **Lecture** **6.** **Modeling of microelectromechanical systems (MEMS). (Lec).** Modeling of microelectromechanical systems (MEMS). | 2 | 2 | PC-3.1, PC-3.2 |
| **1.7** | **Lecture** **7.** **Simulation of heating of a solid body as a result of exposure to laser radiation. (Lec).** Simulation of heating of a solid body as a result of exposure to laser radiation. | 2 | 2 | PC-3.1, PC-3.2 |
| **1.8** | **Lecture** **8.** **Modeling of semiconductor devices.** **(Lec).** Modeling of semiconductor devices. | 2 | 2 | PC-3.1, PC-3.2 |
| **1.9** | **Performing practical tasks (Pr).** PR 1. Introduction to computer modeling, finite element method. | 2 | 2 | PC-3.1, PC-3.2 |
| **1.10** | **Performing practical tasks (Pr).** PR 2. Introduction to COMSOL Multiphysics, getting started, physical interfaces and milestones. | 2 | 2 | PC-3.1, PC-3.2 |
| **1.11** | **Performing practical tasks (Pr).** PR 3. Modeling of heat transfer processes (part 1). | 2 | 2 | PC-3.1, PC-3.2 |
| **1.12** | **Performing practical tasks (Pr).** PR 4. Modeling of heat transfer processes (part 2). | 2 | 2 | PC-3.1, PC-3.2 |
| **1.13** | **Performing practical tasks (Pr).** PR 5. Modeling of heat transfer processes caused by resistive (Joule) heating (part 1). | 2 | 2 | PC-3.1, PC-3.2 |
| **1.14** | **Performing practical tasks (Pr).** PR 6. Modeling of heat transfer processes caused by resistive (Joule) heating (part 2). | 2 | 2 | PC-3.1, PC-3.2 |
| **1.15** | **Performing practical tasks (Pr).** PR 7. Modeling of deformations (part 1) | 2 | 2 | PC-3.1, PC-3.2 |
| **1.16** | **Performing practical tasks (Pr).** PR 8. Modeling of deformations (part 2) | 2 | 2 | PC-3.1, PC-3.2 |
| **1.17** | **Performing practical tasks (Pr).** PR 9. Modeling of microelectromechanical systems (MEMS) (part 1). | 2 | 2 | PC-3.1, PC-3.2 |
| **1.18** | **Performing practical tasks (Pr).** PR 9. Modeling of microelectromechanical systems (MEMS) (part 2). | 2 | 2 | PC-3.1, PC-3.2 |
| **1.19** | **Performing practical tasks (Pr).** PR 11. Simulation of solid body heating as a result of exposure to laser radiation (part 1). | 2 | 2 | PC-3.1, PC-3.2 |
| **1.20** | **Performing practical tasks (Pr).** PR 12. Simulation of solid body heating as a result of exposure to laser radiation (part 2). | 2 | 2 | PC-3.1, PC-3.2 |

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| **1.21** | **Performing practical tasks (Pr).** PR 13. Modeling of electromagnetic radiation distribution in layered nanostructures by the finite element method in COMSOL Multiphysics. Comparison of simulation results obtained by different methods, error estimation (part 1). | 2 | 2 | PC-3.1, PC-3.2 |
| **1.22** | **Performing practical tasks (Pr).** PR 14. Modeling of electromagnetic radiation distribution in layered nanostructures by the finite element method in COMSOL Multiphysics. Comparison of simulation results obtained by different methods, error estimation (part 2). | 2 | 2 | PC-3.1, PC-3.2 |
| **1.23** | **Performing practical tasks (Pr).** PR 15. Simulation of a field-effect transistor with an integrated channel in COMSOL Multiphysics (part 1). | 2 | 2 | PC-3.1, PC-3.2 |
| **1.24** | **Performing practical tasks (Pr).** PR 16. Simulation of a field-effect transistor with an integrated channel in COMSOL Multiphysics (part 2). | 2 | 2 | PC-3.1, PC-3.2 |
| **1.25** | **Performing practical tasks (Pr).** PR 17. Simulation of a field-effect transistor with an induced channel in COMSOL Multiphysics. Photoconductive antennas. Dark current. Transient photocurrent (part 1). | 2 | 2 | PC-3.1, PC-3.2 |
| **1.26** | **Performing practical tasks (Pr).** PR 18. Simulation of a field-effect transistor with an induced channel in COMSOL Multiphysics. Photoconductive antennas. Dark current. Transient photocurrent (part 2). | 2 | 2 | PC-3.1, PC-3.2 |
| **1.27** | **Performing practical tasks (Pr).** PR 19. Modeling of optoelectronic semiconductor devices in COMSOL Multiphysics. Modeling of a p-i-n photodiode (part 1). | 2 | 2 | PC-3.1, PC-3.2 |
| **1.28** | **Performing practical tasks (Pr).** PR 20. Modeling of optoelectronic semiconductor devices in COMSOL Multiphysics. Modeling of a p-i-n photodiode (part 2). | 2 | 2 | PC-3.1, PC-3.2 |
| **1.29** | **Performing practical tasks (Pr).** PR 21. Bipolar Transistor Simulation in COMSOL Multiphysics (part 1). | 2 | 2 | PC-3.1, PC-3.2 |
| **1.30** | **Performing practical tasks (Pr).** PR 22. Bipolar Transistor Simulation in COMSOL Multiphysics (part 2). | 2 | 2 | PC-3.1, PC-3.2 |
| **1.31** | **Performing practical tasks (Pr).** PR 23. Simulation of heating in a bipolar transistor in COMSOL Multiphysics (part 1). | 2 | 2 | PC-3.1, PC-3.2 |

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| **1.32** | **Performing practical tasks (Pr).** PR 24. Simulation of heating in a bipolar transistor in COMSOL Multiphysics (part 2). | | 2 | 2 | PC-3.1, PC-3.2 | |
| **1.33** | **Performing practical tasks (Pr).** PR 25. Design examples in the COMSOL Multiphysics environment: creation of new elements of micro- and nanoelectronics (part 1). | | 2 | 2 | PC-3.1, PC-3.2 | |
| **1.34** | **Performing practical tasks (Pr).** PR 26. Design examples in the COMSOL Multiphysics environment: creation of new elements of micro- and nanoelectronics (part 2). | | 2 | 2 | PC-3.1, PC-3.2 | |
| **1.35** | **Performing practical tasks (Pr).** PR 27. Fundamentals of design in the COMSOL Multiphysics environment: Deformation modeling (part 1). | | 2 | 2 | PC-3.1, PC-3.2 | |
| **1.36** | **Performing practical tasks (Pr).** PR 28. Fundamentals of design in the COMSOL Multiphysics environment: Deformation modeling (part 2). | | 2 | 2 | PC-3.1, PC-3.2 | |
| **1.37** | **Performing practical tasks (Pr).** PR 29. Design examples in the COMSOL Multiphysics environment: Modeling of solid body heating as a result of exposure to laser radiation (part 1). | | 2 | 2 | PC-3.1, PC-3.2 | |
| **1.38** | **Performing practical tasks (Pr).** PR 30. Design examples in the COMSOL Multiphysics environment: Modeling of solid body heating as a result of exposure to laser radiation (part 2). | | 2 | 2 | PC-3.1, PC-3.2 | |
| **1.39** | **Oral interview (Pr).** Questions about the materials of the lecture | | 2 | 2 | PC-3.1, PC-3.2 | |
| **1.40** | **Solution of the control work (Pr).** Security questions for the section | | 2 | 2 | PC-3.1, PC-3.2 | |
| **1.41** | **Homework (IWS).** Execution of practical works | | 2 | 10 | PC-3.1, PC-3.2 | |
| **1.42** | **Preparation for classroom classes (IWS).** Preparation for lectures and practical classes | | 2 | 10 | PC-3.1, PC-3.2 | |
| **1.43** | **Completing coursework** **(project)** **(IWS).** Completing coursework | | 2 | 62 | PC-3.1, PC-3.2 | |
| **2. Intermediate certification (exam)** | | | | | | |
| **2.1** | **Preparation for the intermediate certification (Exam).** | | 2 | 16 | PC-3.1, PC-3.2 | |
| **2.2** | **Contact work with the teacher during the intermediate certification (CWC).** | | 2 | 2,35 | PC-3.1, PC-3.2 | |
| **3. Intermediate certification (Coursework)** | | | | | | |
| **3.1** | **Preparation for the intermediate certification (КР).** | | 2 | 33,65 | PC-3.1, PC-3.2 | |
| **3.2** | **Contact work with the teacher during the intermediate certification (CWC).** | | 2 | 2 | PC-3.1, PC-3.2 | |
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| **5. EVALUATION MATERIALS** | | | | | | |

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| **5.1. List of competencies** | | | | | |
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| List of competencies, the development of which the study of the discipline is aimed at «Simulation using COMSOL Multiphysics», with an indication of the results of their formation in the process of mastering the educational program, presented in paragraph 3 of this work program | | | | | |
| **5.2. Typical control questions and tasks** | | | | | |
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| Interface features (concepts of kernel and workspace (notebook) of the package.  Package reference system.  Embedded modules (add-ons).  The main blocks.  Creating a new project in the studied modeling packages  Basics of the programming language.  The concept of an object.  Types of objects.  A list as a form of internal representation of objects. | | | | | |
| **5.3. Fund of evaluation Materials** | | | | | |
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| A complete list of evaluation materials is provided in the Appendix 1. | | | | | |
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| **6. MATERIAL, TECHNICAL, EDUCATIONAL AND METHODOLOGICAL SUPPORT OF THE DISCIPLINE (MODULE)** | | | | | |
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| **6.1. MATERIAL AND TECHNICAL SUPPORT OF THE DISCIPLINE (МОДУЛЯ)** | | | | | |
| **Name of premises** | | | | **List of main equipment** | |
| Classroom for lectures and seminars, group and individual consultations, ongoing monitoring and intermediate certification | | | | Multimedia equipment, specialized furniture, sets of demonstration equipment and educational and visual aids that provide thematic illustrations. | |
| Specialized Educational and Scientific Laboratory for Modeling and Designing Elements of Microsystem Technology | | | | Computer equipment with the ability to connect to the Internet | |
| A room for independent work of students | | | | Computer equipment with the ability to connect to the Internet and provide access to the electronic information and educational environment of the organization. | |
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| **6.2. LIST OF SOFTWARE** | | | | | |
| 1. |  | Microsoft Windows. Contract No. 32009183466 from 02.07.2021. | | | |
| 2. |  | Microsoft Office. Contract No. 32009183466 from 02.07.2021. | | | |
| 3. |  | COMSOL Multiphysics. Sublicense contract No. 31705027784 from 12.05.2017. | | | |
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| **6.3. RECOMMENDED LITERATURE** | | | | | |
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| **6.3.1. Basic literature** | | | | | |
| 1. |  | Kovalenko A. V., Uzdenova A. M., Urtenov M. H., Nikonenko V. V. Matematicheskoe modelirovanie fiziko-himicheskih processov v srede COMSOL Multiphysics 5.2 [Electronic resource]:. - Sankt-Peterburg: Lan', 2021. - 228 s. – Access mode: https://e.lanbook.com/book/167416 | | | |
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| **6.3.2. Additional literature** | | | | | |

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| 1. |  | Pevtsov E. F. AVTOMATIZACIYA FIZICHESKOGO EKSPERIMENTA [Electronic resource]:. - M.: MIREA, 2013. - 42 s. – Access mode: http://library.mirea.ru/secret/mr\_145.pdf | | |
| 2. |  | Pevtsov E. F., Tarasov I. E., Minnebaev V. M. Avtomatizirovannoe proektirovanie cifrovyh skhem [Electronic resource]:uchebnoe posobie. - M.: MIREA, 2016. - – Access mode: http://library.mirea.ru/secret/ab/1243.iso | | |
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| **6.4. RECOMMENDED LIST OF MODERN PROFESSIONAL DATABASES AND INFORMATION REFERENCE SYSTEMS** | | | | |
| 1. |  | Website of the PTI Department of Nanoelectronics https://fks.mirea.ru | | |
| 2. |  | Russian Technological Journal  https://www.rtj.mirea.ru | | |
| 3. |  | COMSOL Multiphysics® Software for multiphysical modeling https://www.COMSOL.ru | | |
| 4. |  | Information portal of the Russian Science Foundation http://www.rscf.ru | | |
| 5. |  | Russian Foundation for Basic Research https://www.rfbr.ru | | |
| 6. |  | Electronic fund of legal and regulatory technical documentation Tekhnoexpert http://www.docs.cntd.ru | | |
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| **6.5. METHODICAL INSTRUCTIONS FOR STUDENTS STUDYING THE DISCIPLINE (MODULE)** | | | | |
| The student’s independent work is aimed at preparing for academic classes and at developing knowledge, skills and abilities provided for in the discipline program.  In accordance with the curriculum, the discipline may include Lectures, practical classes and Laboratory work, as well as the execution and defense of a course project (work). Successful study of the discipline requires attending all types of classes, completing teacher assignments and familiarization with basic and additional literature. Depending on the activities provided for in the curriculum and section 4 of this program, the student chooses methodological guidelines for independent work from the ones listed below.  When preparing for lecture classes, students need to:  before the next lecture, it is necessary to review the summary of the material of the previous Lectures. If you have difficulties in perceiving the material, you should refer to the main literary sources. If it was not possible to understand the material again, then contact the lecturer (according to the schedule of his consultations) or the teacher in practical classes.  Practical classes complete the study of the most important topics of the discipline. They serve to consolidate the studied material, develop the skills and abilities of preparing reports, messages, gaining experience in oral public speeches, conducting discussions, argumentation and defending the propositions put forward, as well as to monitor the degree of readiness of students in the discipline being studied by the teacher.  When preparing for a practical lesson, students have the opportunity to use the advice of a teacher.  When preparing for practical classes, students need to:  bring with you the literature recommended by the teacher for a specific lesson;  before the next practical lesson on the recommended literary sources, work out the theoretical material corresponding to the topic of the lesson;  at the beginning of classes, ask the teacher questions about the material that caused difficulties in understanding and mastering it when solving tasks set for independent solution;  during the seminar, give specific, clear answers to the substance of the questions;  at the training session, bring each task to the final solution, demonstrate an understanding of the calculations (analyses, situations), in case of difficulties, contact the teacher.  Students who have missed classes (regardless of the reasons), who do not have a written solution to problems or are not prepared for this practical lesson, are recommended to come to the teacher's consultation no later than 2 weeks and report on the topic studied in the lesson. | | | | |

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| The methodological guidelines necessary for studying and passing the discipline are given as part of the educational program. | | |
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| **6.6. METHODOLOGICAL RECOMMENDATIONS FOR THE TRAINING OF PERSONS WITH LIMITED HEALTH OPPORTUNITIES AND THE DISABLED** | | |
| The development of the discipline by students with disabilities can be organized both jointly with other students and in separate groups. Special conditions are assumed for students with disabilities to receive education.  The teaching staff gets acquainted with the psychological and physiological characteristics of students with disabilities and persons with disabilities, individual rehabilitation programs for the disabled (if available). If necessary, additional teaching support is provided by tutors, psychologists, social workers, trained assistants.  In accordance with the methodological recommendations of the Ministry of Education and Science of the Russian Federation (approved April 8, 2014 N AK-44/05vn), the course is supposed to use socially active and reflective teaching methods, technologies of socio-cultural rehabilitation in order to assist in establishing full-fledged interpersonal relationships with other students, creating a comfortable psychological climate in the student group. Selection and development of educational materials are made taking into account the provision of material in various forms: auditory, visual, using special technical means and information systems.  Mediamaterials should also be used and adapted taking into account the individual characteristics of the training of persons with disabilities.  The development of the discipline by persons with disabilities is carried out using general and special purpose teaching tools (personal and collective use). Material and technical support provides for the adaptation of classrooms to the needs of persons with disabilities.  The form of certification for students with disabilities is established taking into account individual psychophysical characteristics. For students with HIA, an accessible form of assignment of assessment tools is provided, namely:  - in printed or electronic form (for persons with disorders of the musculoskeletal system);  - in printed or electronic form with enlarged font and contrast (for persons with hearing, speech, vision impairments);  - reading the task aloud by the assistant (for visually impaired persons).  Students with disabilities have increased time to prepare answers to control questions. For such students, an accessible form of providing answers to tasks is provided, namely:  - written on paper or a set of answers on a computer (for persons with hearing and speech impairments);  - choosing an answer from possible options using the services of an assistant (for people with musculoskeletal disorders);  - oral interview (for persons with visual impairments, musculoskeletal system).  If necessary, for students with disabilities, the procedure for evaluating learning outcomes can be carried out in several stages. | | |

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| MINISTRY OF SCIENCE AND HIGHER EDUCATION OF THE RUSSIAN FEDERATION | | | | | | | | | | | | | | | | | | | | | |
| Federal State Budget Educational Institution of Higher Education  «MIREA – Russian Technological University» | | | | | | | | | | | | | | | | | | | | | |
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| Working program of the discipline (module) | | | | | | | | | | | | | | | | | | | | | |
| **Low-dimensional systems** | | | | | | | | | | | | | | | | | | | | | |
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|  | Department leading the training | | | | | |  |  | **Department of Nanoelectronics** | | | | | | | | | | | | |
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|  | Direction of training | | | | | | |  | **11.04.04 Electronics and nanoelectronics** | | | | | | | | | | | | |
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|  | Profile | | | | | | |  | **Engineering of modern materials for information technology, renewable energy and sensing** | | | | | | | | | | | | |
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|  | Qualification | | | | |  |  |  | **Master** | | | | | | | | | | | | |
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|  | Form of education | | | | |  |  |  | **Full-time** | | | | | | | | | |  |  |  |
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|  | Total labor intensity | | | |  |  |  |  | **5 credits** | | | | | | | | | |  |  |  |
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| **Distribution of discipline hours and forms of intermediate certification by semesters** | | | | | | | | | | | | | | | | | | | | | |
| Semester | | Credits | Distribution of hours | | | | | | | | | | | | | | | Forms of intermediate attestation | | |  |
| Total | Lectures | | | | Laboratory work | | | Practical classes | Independent work of students | | Contact work during practice and (or) certification | | | Control of training |  |
| 1 | | 5 | 180 | 16 | | | | 0 | | | 48 | 80 | | 2,35 | | | 33,65 | Exam | | |  |
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| The program was made by: |  |  |  |  |
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| *Doctor of Science in Physico-mathematical Sciences, Professor, V. Morozov \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_* | | | | |
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| Working program of the discipline | | |  |  |
| **Low-dimensional systems** | | | | |
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| it is developed in accordance with FSES HE: | | |  |  |
| Federal State Educational Standard of Higher Education - Magistracy in the Direction of training 11.04.04 Electronics and nanoelectronics (order of the Ministry of Science and Higher Education of the Russian Federation from 22.09.2017. № 959) | | | | |
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| it is based on the curriculum: | | |  |  |
| Direction of training: 11.04.04 Electronics and nanoelectronics  Profile: «Engineering of modern materials for information technology, renewable energy and sensing» | | | | |
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| The working program was approved at the meeting of the department | | | | |
| **Department of Nanoelectronics** | | | | |
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| Minutes of meeting from 02.03.2021 № 3  Head of the Department A. Sigov \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ | | | | |

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| **Approval of the WPD for execution in the next academic year** | | | | |
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| The working program was revised, discussed and approved for execution in the 2022-2023 academic year at a meeting of the department | | | | |
| **Department of Nanoelectronics** | | | | |
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|  | Minutes of meeting from \_\_ \_\_\_\_\_\_\_\_\_\_ 2022. № \_\_  Head of the Department \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ | | | |
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| **Approval of the WPD for execution in the next academic year** | | | | |
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| The working program was revised, discussed and approved for execution in the 2023-2024 academic year at a meeting of the department | | | | |
| **Department of Nanoelectronics** | | | | |
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|  | Minutes of meeting from \_\_ \_\_\_\_\_\_\_\_\_\_ 2023. № \_\_  Head of the Department \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ | | | |
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| **Approval of the WPD for execution in the next academic year** | | | | |
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| The working program was revised, discussed and approved for execution in the 2024-2025 academic year at a meeting of the department | | | | |
| **Department of Nanoelectronics** | | | | |
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|  | Minutes of meeting from \_\_ \_\_\_\_\_\_\_\_\_\_ 2024. № \_\_  Head of the Department \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ | | | |
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| **Approval of the WPD for execution in the next academic year** | | | | |
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| The working program was revised, discussed and approved for execution in the 2025-2026 academic year at a meeting of the department | | | | |
| **Department of Nanoelectronics** | | | | |
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|  | Minutes of meeting from \_\_ \_\_\_\_\_\_\_\_\_\_ 2025. № \_\_  Head of the Department \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ | | | |
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| **1. OBJECTIVES OF MASTERING THE DISCIPLINE (MODULE)** | | | | | |
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| The discipline «Low-dimensional systems» aims to contribute to the formation of students’ competencies, provided by this work program in accordance with the requirements of FSES HE in the direction of training 11.04.04 Electronics and nanoelectronics, taking into account the specifics of the profile – «Engineering of modern materials for information technology, renewable energy and sensing». | | | | | |
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| **2. PLACE OF DISCIPLINE (MODULE) IN THE STRUCTURE OF THE EDUCATIONAL PROGRAM** | | | | | |
|  | Direction of training: |  | 11.04.04 Electronics and nanoelectronics | | |
|  |
|  | Profile: |  | Engineering of modern materials for information technology, renewable energy and sensing | | |
|  |  |  |
|  | Block: |  | Disciplines (modules) | | |
|  |  |  |
|  | Part: |  | Mandatory part | | |
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|  | Total labor intensity: |  | 5 credits (180 academic hours). | | |
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| **3. THE STUDENT’S COMPETENCIES FORMED AS A RESULT OF MASTERING THE DISCIPLINE (MODULE)** | | | | | |
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| As a result of mastering the practice, the student must master the following competencies: | | | | | |
| **GPC-1** - Capable to present a modern scientific picture of the world, identify the natural science essence of problems, determine ways to solve them and evaluate the effectiveness of the choice made | | | | | |
| **GPC-2** - Capable to apply modern research methods, present and argumentatively defend the results of the work performed | | | | | |
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| **PLANNED RESULTS OF TRAINING IN THE DISCIPLINE (MODULE), CHARACTERIZING THE FORMATION OF COMPETENCIES** | | | | | |
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| **GPC-1 : Capable to present a modern scientific picture of the world, identify the natural science essence of problems, determine ways to solve them and evaluate the effectiveness of the choice made** | | | | | |
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| **GPC-1.1: Reveals the natural science essence of the problem in the field of electronics** | | | | | |
| **To know:** | | | | | |
| - basic physical models of low-dimensional systems | | | | | |
| **Be able to:** | | | | | |
| - apply physical considerations to the choice of a model of a real low-dimensional system | | | | | |
| **Possess:** | | | | | |
| - skills in solving standard problems in the field of low-dimensional systems | | | | | |
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| **GPC-2 : Capable to apply modern research methods, present and argumentatively defend the results of the work performed** | | | | | |
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| **GPC-2.1: Applies modern research methods in the field of electronics** | | | | | |
| **To know:** | | | | | |
| - features of quantum states of charge carriers in typical low-dimensional systems | | | | | |
| **Be able to:** | | | | | |
| - evaluate the values of parameters that determine the electronic properties of nanosystems | | | | | |
| **Possess:** | | | | | |

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| - skills of analyzing physical effects used in modern electronics | | | | | | |
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| **AS A RESULT OF STUDYING THE DISCIPLINE (MODULE), THE STUDENT MUST** | | | | | | |
|  |  |  |  |  |  |  |
| **To know:** | | | | | | |
| - features of quantum states of charge carriers in typical low-dimensional systems | | | | | | |
| - basic physical models of low-dimensional systems | | | | | | |
| **Be able to:** | | | | | | |
| - evaluate the values of parameters that determine the electronic properties of nanosystems | | | | | | |
| - apply physical considerations to the choice of a model of a real low-dimensional system | | | | | | |
| **Possess:** | | | | | | |
| - skills of analyzing physical effects used in modern electronics | | | | | | |
| - skills in solving standard problems in the field of low-dimensional systems | | | | | | |
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| **4. STRUCTURE AND CONTENT OF THE DISCIPLINE (MODULE)** | | | | | | |
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| During the training sessions, the organization ensures the development of students’ teamwork skills, interpersonal communication, decision-making and leadership qualities. | | | | | | |
| **Code** | **Name of sections and topics /type of classes/** | | **Semester** | **Academic Hours** | **Competencies** | |
| **1. Properties of low-dimensional systems** | | | | | | |
| **1.1** | **Lecture** **1.** **Introduction. Quantum dimensional effects. (Lec).** The concept of dimensional effects in crystals. Types of dimensional effects. Classic dimensional effects. Ballistic transport. Mesoscopic systems. The concept of quantum dimensional effects. Quantum dots. Quantum wires. Two-dimensional electron gas | | 1 | 2 | GPC-1.1 | |
| **1.2** | **Lecture** **2.** **Quantum wells in nanostructures. Quantum barriers in nanostructures** **(Lec).** One-dimensional potential pits. The coefficient of passage of quasiparticles over the quantum well. Virtual energy levels. Two-dimensional and three-dimensional pits in nanostructures. The coefficient of passage of a potential barrier by a quasiparticle. Quantum tunneling. "Transparent” and "quasi-classical" potential barriers. | | 1 | 2 | GPC-1.1 | |
| **1.3** | **Lecture** **3.** **Energy density of electronic states in low-dimensional structures (Lec).** Energy density of states in one-dimensional and two-dimensional electron gas. Fermi energy in low-dimensional electron gases. | | 1 | 2 | GPC-1.1 | |
| **1.4** | **Lecture** **4.** **Quantum resistors and quantum contacts (Lec).** The conductivity of a quantum resistor. The conductivity of a quantum point contact. Serial connection of quantum resistors. Resonant tunneling. | | 1 | 2 | GPC-1.1 | |

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| **1.5** | **Lecture** **5.** **Contact phenomena in crystal structures (Lec).** Contacts: metal-metal, metal-semiconductor, metal-dielectric-semiconductor. The concept of an inversion layer. The MOSFET is a field-effect transistor. Formation of a degenerate two-dimensional electron gas in a strong field. | 1 | 2 | GPC-1.1 |
| **1.6** | **Lecture** **6.** **Quantum Hall effect** **(Lec).** Integer quantum Hall effect in a two-dimensional electron gas. Fractional quantum Hall effect. | 1 | 2 | GPC-2.1 |
| **1.7** | **Lecture** **7.** **Electronic states in nanoclusters** **(Lec).** The main types of nanoclusters. Thermodynamics of nanoclusters. Electronic states in metallic and semiconductor nanoclusters. Shell model of metal nanoclusters. | 1 | 2 | GPC-2.1 |
| **1.8** | **Lecture** **8.** **Charge transfer in quantum dots (Lec).** Types of quantum dots. Electronic states in quantum dots. Single-electron transport via quantum dots. Coulomb blockade of tunneling. | 1 | 2 | GPC-2.1 |
| **1.9** | **Performing practical tasks (Pr).** PR 1. Conditions for the appearance of classical and quantum dimensional effects in crystals. Oral interview. | 1 | 2 | GPC-1.1, GPC -2.1 |
| **1.10** | **Performing practical tasks (Pr).** PR 2. Determination of the effective dimension of real nanostructures | 1 | 2 | GPC-1.1, GPC -2.1 |
| **1.11** | **Performing practical tasks (Pr).** PR 3. Wave functions of electrons in low-dimensional structures. | 1 | 2 | GPC-1.1, GPC -2.1 |
| **1.12** | **Performing practical tasks (Pr).** PR 4. Localized states of electrons in quantum wells. Oral interview. | 1 | 2 | GPC-1.1, GPC -2.1 |
| **1.13** | **Performing practical tasks (Pr).** PR 5. Solving problems on the topic “Quantum barriers in nanostructures” | 1 | 2 | GPC-1.1, GPC -2.1 |
| **1.14** | **Performing practical tasks (Pr).** PR 6. Qualitative analysis of quantum states of electrons in low-dimensional structures with wells and barriers | 1 | 2 | GPC-1.1, GPC -2.1 |
| **1.15** | **Performing practical tasks (Pr).** PR 7. Solving problems on the topic “The density of states in a low-dimensional electron gas”. | 1 | 2 | GPC-1.1, GPC -2.1 |
| **1.16** | **Performing practical tasks (Pr).** PR 8. Calculation of Fermi energy in a low-dimensional electron gas. | 1 | 2 | GPC-1.1, GPC -2.1 |
| **1.17** | **Performing practical tasks (Pr).** PR 9. Qualitative analysis of the curvature of energy zones in semiconductor structures | 1 | 2 | GPC-1.1, GPC -2.1 |

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| **1.18** | **Performing practical tasks (Pr).** PR 10. Building a qualitative picture of energy zones in the contact area. | 1 | 2 | GPC-1.1, GPC -2.1 |
| **1.19** | **Performing practical tasks (Pr).** PR 11. Scheme of energy zones in double heterostructures | 1 | 2 | GPC-1.1, GPC -2.1 |
| **1.20** | **Performing practical tasks (Pr).** PR 12. Solution of the stationary Schrodinger equation for an electron in a magnetic field. | 1 | 2 | GPC-1.1, GPC -2.1 |
| **1.21** | **Performing practical tasks (Pr).** PR 13. Calibration transformations of the magnetic field and wave functions of electrons | 1 | 2 | GPC-1.1, GPC -2.1 |
| **1.22** | **Performing practical tasks (Pr).** PR 14. The wave function of an electron in a weak magnetic field. Parallel connection of quantum resistors. | 1 | 2 | GPC-1.1, GPC -2.1 |
| **1.23** | **Performing practical tasks (Pr).** PR 15. Properties of conductivity tensors and resistances of a two-dimensional electron gas. Oral interview. | 1 | 2 | GPC-1.1, GPC -2.1 |
| **1.24** | **Performing practical tasks (Pr).** PR 16. Calculation of conductivity and resistance tensors using the kinetic equation | 1 | 2 | GPC-1.1, GPC -2.1 |
| **1.25** | **Performing practical tasks (Pr).** PR 17. Electronic states in nanoclusters. | 1 | 2 | GPC-1.1, GPC -2.1 |
| **1.26** | **Performing practical tasks (Pr).** PR 18. Classical and quantum modes of Coulomb blockade in quantum dots | 1 | 2 | GPC-1.1, GPC -2.1 |
| **1.27** | **Oral interview (Pr).** Questions about the materials of the lecture | 1 | 2 | GPC-1.1, GPC -2.1 |
| **1.28** | **Oral interview (Pr).** Questions about the materials of the lecture | 1 | 2 | GPC-1.1, GPC -2.1 |
| **1.29** | **Oral interview (Pr).** Questions about the materials of the lecture | 1 | 2 | GPC-1.1, GPC -2.1 |
| **1.30** | **Oral interview (Pr).** Questions about the materials of the lecture | 1 | 2 | GPC-1.1, GPC -2.1 |
| **1.31** | **Oral interview (Pr).** Questions about the materials of the lecture | 1 | 2 | GPC-1.1, GPC -2.1 |
| **1.32** | **Solution of the control work (Pr).** Security questions for the section | 1 | 2 | GPC-1.1, GPC -2.1 |
| **1.33** | **Preparation for classroom classes (IWS).** Preparation for lectures and practical classes | 1 | 40 | GPC-1.1, GPC -2.1 |
| **1.34** | **Homework (IWS).** Acquisition of problem solving skills on lecture topics | 1 | 40 | GPC-1.1, GPC -2.1 |
| **2. Intermediate certification (exam)** | | | | |
| **2.1** | **Preparation for the intermediate certification (Exam).** | 1 | 33,65 | GPC-1.1, GPC -2.1 |

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| **2.2** | | | **Contact work with the teacher during the intermediate certification (CWC).** | | | 1 | 2,35 | GPC-1.1, GPC -2.1 | |
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| **5. EVALUATION MATERIALS** | | | | | | | | | |
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| **5.1. List of competencies** | | | | | | | | | |
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| List of competencies, the development of which the study of the discipline is aimed at «Low-dimensional systems», with an indication of the results of their formation in the process of mastering the educational program, presented in paragraph 3 of this work program | | | | | | | | | |
| **5.2. Typical control questions and tasks** | | | | | | | | | |
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| 1. What are "classical dimensional effects"? How do they manifest themselves in electronics?  2. What are "quantum dimensional effects"? How do they manifest themselves in electronics?  3. To define models of nanostructures: nanocluster, quantum dot, quantum wire, two-dimensional electron (hole) gas.  4. Write down general expressions for the wave function of the stationary state of an electron (hole) in one-dimensional and two-dimensional nanostructures (in the approximation of the effective mass).  5. What are "energy subzones" in low-dimensional structures?  6. Describe the scheme of numerical calculation of the energy spectrum of a quasiparticle (electron or hole) in a one-dimensional rectangular potential well.  7. Describe the output scheme of the expression for the quasiparticle passage coefficient over a one-dimensional rectangular potential well.  Sample topics of oral messages in practical classes:  1. Localized quantum states of quasiparticles in asymmetric potential wells.  2. The passage of quasiparticles over an asymmetric potential well.  3. The energy density of electronic (hole) states in a one-dimensional structure with several subzones.  4. Energy density of electronic (hole) states in a two-dimensional structure with several subzones.  5. The effect of resonant tunneling in nanoelectronics.  6. The behavior of the electric potential in the region of a sharp heterojunction.  7. Heterolasers. | | | | | | | | | |
| **5.3. Fund of evaluation Materials** | | | | | | | | | |
| A complete list of evaluation materials is provided in the Appendix 1. | | | | | | | | | |
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| **6. MATERIAL, TECHNICAL, EDUCATIONAL AND METHODOLOGICAL SUPPORT OF THE DISCIPLINE (MODULE)** | | | | | | | | | |
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| **6.1. MATERIAL AND TECHNICAL SUPPORT OF THE DISCIPLINE (МОДУЛЯ)** | | | | | | | | | |
| **Name of premises** | | | | | **List of main equipment** | | | | |
| A room for independent work of students | | | | | Computer equipment with the ability to connect to the Internet and provide access to the electronic information and educational environment of the organization. | | | | |
| Classroom for lectures and seminars, group and individual consultations, ongoing monitoring and intermediate certification | | | | | Multimedia equipment, specialized furniture, sets of demonstration equipment and educational and visual aids that provide thematic illustrations. | | | | |
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| **6.2. LIST OF SOFTWARE** | | | | | | | | | |
| 1. |  | Microsoft Windows. Contract No. 32009183466 from 02.07.2021. | | | | | | | |

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| 2. |  | Microsoft Office. Contract No. 32009183466 from 02.07.2021. | | |
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| **6.3. RECOMMENDED LITERATURE** | | | | |
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| **6.3.1. Basic literature** | | | | |
| 1. |  | Morozov V. G. Termodinamika i statisticheskaya fizika:uchebnoe posobie. - M.: MIREA, 2018. - 244 s. | | |
| 2. |  | Morozov V. G. Fizika nizkorazmernyh struktur [Electronic resource]:uchebnoe posobie. - M.: RTU MIREA, 2019. - – Access mode: http://library.mirea.ru/secret/31012020/2254.iso | | |
| 3. |  | Shchuka A. A., Sigov A. S. Nanoelektronika [Electronic resource]:Uchebnik dlya vuzov. - Moscow: YUrajt, 2021. - 297 s – Access mode: https://urait.ru/bcode/470007 | | |
| 4. |  | Efremov Yu. S. Statisticheskaya fizika i termodinamika [Electronic resource]:Uchebnoe posobie dlya vuzov. - Moscow: YUrajt, 2021. - 209 s – Access mode: https://urait.ru/bcode/472899 | | |
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| **6.3.2. Additional literature** | | | | |
| 1. |  | Bondarev B. V., Kalashnikov N. P., Spirin G. G. Kurs obshchej fiziki v 3 kn. Kniga 3: termodinamika, statisticheskaya fizika, stroenie veshchestva [Electronic resource]:Uchebnik dlya bakalavrov. - Moscow: YUrajt, 2019. - 369 s – Access mode: https://urait.ru/bcode/425491 | | |
| 2. |  | Borisenko V. E., Vorob'eva A. I., Danilyuk A. L., Utkina E. A. Nanoelektronika: teoriya i praktika:Uchebnik dlya vuzov. - M.: BINOM. Laboratoriya znanij, 2013. - 366 s. | | |
| 3. |  | Gavrilenko V. G., Petrov E. YU. Sbornik zadach po kursu “Termodinamika i statisticheskaya fizika” [Electronic resource]:uchebno-metodicheskoe posobie. - Nizhnij Novgorod: NNGU im. N. I. Lobachevskogo, 2019. - 10 s. – Access mode: https://e.lanbook.com/book/144963 | | |
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| **6.4. RECOMMENDED LIST OF MODERN PROFESSIONAL DATABASES AND INFORMATION REFERENCE SYSTEMS** | | | | |
| 1. |  | Website of the PTI Department of Nanoelectronics https://fks.mirea.ru | | |
| 2. |  | Database Web of Science  http://www.webofknowledge.com | | |
| 3. |  | Elektronika NTB - scientific and technical journal  http://www.electronics.ru | | |
| 4. |  | Russian Technological Journal  https://www.rtj.mirea.ru | | |
| 5. |  | Foundation for the Promotion of Innovation  http://www.fasie.ru | | |
| 6. |  | Natural Science educational Portal http://www.en.edu.ru | | |
| 7. |  | Scientific Electronic Library http://www.elibrary.ru | | |
| 8. |  | Information portal of the Russian Science Foundation http://www.rscf.ru | | |
| 9. |  | Russian Foundation for Basic Research https://www.rfbr.ru | | |
| 10. |  | Information portal «Popular nanotechnologies» http://www.popnano.ru | | |
| 11. |  | Nanometer - Nanotechnology community http://www.nanometer.ru | | |
| 12. |  | NanoNewsNet.ru- non-commercial on-line publication dedicated to the nanoindustry http://www.old.nanonewsnet.ru | | |
| 13. |  | Electronic fund of legal and regulatory technical documentation Tekhnoexpert http://www.docs.cntd.ru | | |
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| **6.5. METHODICAL INSTRUCTIONS FOR STUDENTS STUDYING THE DISCIPLINE (MODULE)** | | | | |
| The student’s independent work is aimed at preparing for academic classes and at developing knowledge, skills and abilities provided for in the discipline program. | | | | |

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| In accordance with the curriculum, the discipline may include Lectures, practical classes and Laboratory work, as well as the execution and defense of a course project (work). Successful study of the discipline requires attending all types of classes, completing teacher assignments and familiarization with basic and additional literature. Depending on the activities provided for in the curriculum and section 4 of this program, the student chooses methodological guidelines for independent work from the ones listed below.  When preparing for lecture classes, students need to:  before the next lecture, it is necessary to review the summary of the material of the previous Lectures. If you have difficulties in perceiving the material, you should refer to the main literary sources. If it was not possible to understand the material again, then contact the lecturer (according to the schedule of his consultations) or the teacher in practical classes.  Practical classes complete the study of the most important topics of the discipline. They serve to consolidate the studied material, develop the skills and abilities of preparing reports, messages, gaining experience in oral public speeches, conducting discussions, argumentation and defending the propositions put forward, as well as to monitor the degree of readiness of students in the discipline being studied by the teacher.  When preparing for a practical lesson, students have the opportunity to use the advice of a teacher.  When preparing for practical classes, students need to:  bring with you the literature recommended by the teacher for a specific lesson;  before the next practical lesson on the recommended literary sources, work out the theoretical material corresponding to the topic of the lesson;  at the beginning of classes, ask the teacher questions about the material that caused difficulties in understanding and mastering it when solving tasks set for independent solution;  during the seminar, give specific, clear answers to the substance of the questions;  at the training session, bring each task to the final solution, demonstrate an understanding of the calculations (analyses, situations), in case of difficulties, contact the teacher.  Students who have missed classes (regardless of the reasons), who do not have a written solution to problems or are not prepared for this practical lesson, are recommended to come to the teacher’s consultation no later than 2 weeks and report on the topic studied in the lesson.  The methodological guidelines necessary for studying and passing the discipline are given as part of the educational program. | | |
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| **6.6. METHODOLOGICAL RECOMMENDATIONS FOR THE TRAINING OF PERSONS WITH LIMITED HEALTH OPPORTUNITIES AND THE DISABLED** | | |
| The development of the discipline by students with disabilities can be organized both jointly with other students and in separate groups. Special conditions are assumed for students with disabilities to receive education.  The teaching staff gets acquainted with the psychological and physiological characteristics of students with disabilities and persons with disabilities, individual rehabilitation programs for the disabled (if available). If necessary, additional teaching support is provided by tutors, psychologists, social workers, trained assistants.  In accordance with the methodological recommendations of the Ministry of Education and Science of the Russian Federation (approved April 8, 2014 N AK-44/05vn), the course is supposed to use socially active and reflective teaching methods, technologies of socio-cultural rehabilitation in order to assist in establishing full-fledged interpersonal relationships with other students, creating a comfortable psychological climate in the student group. Selection and development of educational materials are made taking into account the provision of material in various forms: auditory, visual, using special technical means and information systems. | | |

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| Mediamaterials should also be used and adapted taking into account the individual characteristics of the training of persons with disabilities.  The development of the discipline by persons with disabilities is carried out using general and special purpose teaching tools (personal and collective use). Material and technical support provides for the adaptation of classrooms to the needs of persons with disabilities.  The form of certification for students with disabilities is established taking into account individual psychophysical characteristics. For students with HIA, an accessible form of assignment of assessment tools is provided, namely:  - in printed or electronic form (for persons with disorders of the musculoskeletal system);  - in printed or electronic form with enlarged font and contrast (for persons with hearing, speech, vision impairments);  - reading the task aloud by the assistant (for visually impaired persons).  Students with disabilities have increased time to prepare answers to control questions. For such students, an accessible form of providing answers to tasks is provided, namely:  - written on paper or a set of answers on a computer (for persons with hearing and speech impairments);  - choosing an answer from possible options using the services of an assistant (for people with musculoskeletal disorders);  - oral interview (for persons with visual impairments, musculoskeletal system).  If necessary, for students with disabilities, the procedure for evaluating learning outcomes can be carried out in several stages. |

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| MINISTRY OF SCIENCE AND HIGHER EDUCATION OF THE RUSSIAN FEDERATION | | | | | | | | | | | | | | | | | | | | | |
| Federal State Budget Educational Institution of Higher Education  «MIREA – Russian Technological University» | | | | | | | | | | | | | | | | | | | | | |
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| Working program of the discipline (module) | | | | | | | | | | | | | | | | | | | | | |
| **Optical materials and optical operation for information technologies** | | | | | | | | | | | | | | | | | | | | | |
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|  | Department leading the training | | | | | |  |  | **Department of Nanoelectronics** | | | | | | | | | | | | |
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|  | Direction of training | | | | | | |  | **11.04.04 Electronics and nanoelectronics** | | | | | | | | | | | | |
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|  | Profile | | | | | | |  | **Engineering of modern materials for information technology, renewable energy and sensing** | | | | | | | | | | | | |
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|  | Qualification | | | | |  |  |  | **Master** | | | | | | | | | | | | |
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|  | Form of education | | | | |  |  |  | **Full-time** | | | | | | | | | |  |  |  |
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|  | Total labor intensity | | | |  |  |  |  | **5 credits** | | | | | | | | | |  |  |  |
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| **Distribution of discipline hours and forms of intermediate certification by semesters** | | | | | | | | | | | | | | | | | | | | | |
| Semester | | Credits | Distribution of hours | | | | | | | | | | | | | | | Forms of intermediate attestation | | |  |
| Total | Lectures | | | | Laboratory work | | | Practical classes | Independent work of students | | Contact work during practice and (or) certification | | | Control of training |  |
| 2 | | 5 | 180 | 16 | | | | 0 | | | 48 | 80 | | 2,35 | | | 33,65 | Exam | | |  |
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| The program was made by: |  |  |  |  |
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| *Ph.D. Physics and Mathematics, Associate Professor, I. Gladyshev \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_* | | | | |
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| Working program of the discipline | | |  |  |
| **Optical materials and optical operation for information technologies** | | | | |
|  |  |  |  |  |
| it is developed in accordance with FSES HE: | | |  |  |
| Federal State Educational Standard of Higher Education - Magistracy in the Direction of training 11.04.04 Electronics and nanoelectronics (order of the Ministry of Science and Higher Education of the Russian Federation from 22.09.2017. № 959) | | | | |
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| it is based on the curriculum: | | |  |  |
| Direction of training: 11.04.04 Electronics and nanoelectronics  Profile: «Engineering of modern materials for information technology, renewable energy and sensing» | | | | |
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| The working program was approved at the meeting of the department | | | | |
| **Department of Nanoelectronics** | | | | |
|  |  |  |  |  |
| Minutes of meeting from 02.03.2021 № 3  Head of the Department A. Sigov \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ | | | | |

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| **Approval of the WPD for execution in the next academic year** | | | | |
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| The working program was revised, discussed and approved for execution in the 2022-2023 academic year at a meeting of the department | | | | |
| **Department of Nanoelectronics** | | | | |
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|  | Minutes of meeting from \_\_ \_\_\_\_\_\_\_\_\_\_ 2022. № \_\_  Head of the Department \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ | | | |
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| **Approval of the WPD for execution in the next academic year** | | | | |
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| The working program was revised, discussed and approved for execution in the 2023-2024 academic year at a meeting of the department | | | | |
| **Department of Nanoelectronics** | | | | |
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|  | Minutes of meeting from \_\_ \_\_\_\_\_\_\_\_\_\_ 2023. № \_\_  Head of the Department \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ | | | |
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| **Approval of the WPD for execution in the next academic year** | | | | |
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| The working program was revised, discussed and approved for execution in the 2024-2025 academic year at a meeting of the department | | | | |
| **Department of Nanoelectronics** | | | | |
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|  | Minutes of meeting from \_\_ \_\_\_\_\_\_\_\_\_\_ 2024. № \_\_  Head of the Department \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ | | | |
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| **Approval of the WPD for execution in the next academic year** | | | | |
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| The working program was revised, discussed and approved for execution in the 2025-2026 academic year at a meeting of the department | | | | |
| **Department of Nanoelectronics** | | | | |
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|  | Minutes of meeting from \_\_ \_\_\_\_\_\_\_\_\_\_ 2025. № \_\_  Head of the Department \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ | | | |
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| **1. OBJECTIVES OF MASTERING THE DISCIPLINE (MODULE)** | | | | | |
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| The discipline «Optical materials and optical operation for information technologies» aims to contribute to the formation of students’ competencies, provided by this work program in accordance with the requirements of FSES HE in the direction of training 11.04.04 Electronics and nanoelectronics, taking into account the specifics of the profile – «Engineering of modern materials for information technology, renewable energy and sensing». | | | | | |
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| **2. PLACE OF DISCIPLINE (MODULE) IN THE STRUCTURE OF THE EDUCATIONAL PROGRAM** | | | | | |
|  | Direction of training: |  | 11.04.04 Electronics and nanoelectronics | | |
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|  | Profile: |  | Engineering of modern materials for information technology, renewable energy and sensing | | |
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|  | Block: |  | Disciplines (modules) | | |
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|  | Part: |  | Part of the curriculum formed by the participants of educational | | |
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|  | Total labor intensity: |  | 5 credits (180 academic hours). | | |
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| **3. THE STUDENT’S COMPETENCIES FORMED AS A RESULT OF MASTERING THE DISCIPLINE (MODULE)** | | | | | |
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| As a result of mastering the practice, the student must master the following competencies: | | | | | |
| **PC-1** - Capable to apply in-depth knowledge of the structure, physical, physicochemical properties, the purpose of nanomaterials and nanostructures, and methods of measuring their parameters | | | | | |
| **PC-2** - Capable to participate in the development and implementation of modern technological processes, the master of new equipment, technological equipment, the necessary modes of production of micro- and nanoelectronics | | | | | |
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| **PLANNED RESULTS OF TRAINING IN THE DISCIPLINE (MODULE), CHARACTERIZING THE FORMATION OF COMPETENCIES** | | | | | |
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| **PC-1 : Capable to apply in-depth knowledge of the structure, physical, physicochemical properties, the purpose of nanomaterials and nanostructures, and methods of measuring their parameters** | | | | | |
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| **PC-1.2: Analyzes the technological problem at the given norms of technological production, highlighting its basic components and searches for reliable information to solve it for various types of queries** | | | | | |
| **To know:** | | | | | |
| - basic concepts, definitions and laws of various sections of optics | | | | | |
| **Be able to:** | | | | | |
| - evaluate the limits of applicability of the results obtained by various methods | | | | | |
| **Possess:** | | | | | |
| - methods of experimental investigation of the properties of optical materials | | | | | |
|  |  |  |  |  |  |
| **PC-2 : Capable to participate in the development and implementation of modern technological processes, the master of new equipment, technological equipment, the necessary modes of production of micro- and nanoelectronics** | | | | | |

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| **PC-2.1: Participates in the development and implementation of modern technological processes, the development of new equipment, technological equipment, the necessary modes of production of micro- and nanoelectronics products** | | | | | | |
| **To know:** | | | | | | |
| - structure and basic properties of optical materials | | | | | | |
| **Be able to:** | | | | | | |
| - carry out work in the field of optical materials research | | | | | | |
| **Possess:** | | | | | | |
| - methods of studying the properties of optical materials | | | | | | |
| **PC-2.2: Evaluates optimal processes and modes in the development of electronics products** | | | | | | |
| **To know:** | | | | | | |
| - the main manufacturing technologies of fiber light guides | | | | | | |
| **Be able to:** | | | | | | |
| - carry out measurements of optical, photometric and electrical quantities | | | | | | |
| **Possess:** | | | | | | |
| - typical methods of performing optical measurements of various quantities and characteristics | | | | | | |
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| **AS A RESULT OF STUDYING THE DISCIPLINE (MODULE), THE STUDENT MUST** | | | | | | |
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| **To know:** | | | | | | |
| - the main manufacturing technologies of fiber light guides | | | | | | |
| - structure and basic properties of optical materials | | | | | | |
| - basic concepts, definitions and laws of various sections of optics | | | | | | |
| **Be able to:** | | | | | | |
| - carry out measurements of optical, photometric and electrical quantities | | | | | | |
| - carry out work in the field of optical materials research | | | | | | |
| - evaluate the limits of applicability of the results obtained by various methods | | | | | | |
| **Possess:** | | | | | | |
| - typical methods of performing optical measurements of various quantities and characteristics | | | | | | |
| - methods of studying the properties of optical materials | | | | | | |
| - methods of experimental investigation of the properties of optical materials | | | | | | |
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| **4. STRUCTURE AND CONTENT OF THE DISCIPLINE (MODULE)** | | | | | | |
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| During the training sessions, the organization ensures the development of students’ teamwork skills, interpersonal communication, decision-making and leadership qualities. | | | | | | |
| **Code** | **Name of sections and topics /type of classes/** | | **Semester** | **Academic Hours** | **Competencies** | |
| **1. Optical materials and optical operation** | | | | | | |
| **1.1** | **Lecture** **1.** **Introduction. Mechanisms of formation of optical properties of condensed media (Lec).** The subject, goals and objectives of the course. Optical materials: concepts, varieties. The role of optical materials in optoinformatics. Fundamentals of physics of optical phenomena in solids. | | 2 | 2 | PC-1.2 | |

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| **1.2** | **Lecture** **2.** **Operational properties of optical glasses.** **(Lec).** The structure of glass and the basics of the conduction mechanism. The basic statistical equation of the conductivity of glasses. The principle of forming the refractive index profile in the elements of gradient optics. Features of ion exchange processes between glasses and molten salts, between glasses and aqueous solutions of electrolytes. Chemical resistance of glasses. Influence of glass components on chemical stability. | 2 | 2 | PC-1.2, PC- 2.1, PC-2.2 |
| **1.3** | **Lecture** **3.** **Waveguides: Planar, Cylindrical. Losses in optical fibers. Dispersion in optical fibers.** **(Lec).** Waveguide modes. Effective refractive index. Mod speeds. The mod schemes. The distribution of the field in fashion. Variance. Capture angle and numerical aperture. Modes of a cylindrical waveguide. The number of mods. Mod structure. Single-mode fibers. The mod schemes. Gaussian fashion. Absorption losses. Gradient fibers. Intermode variance. Material dispersion. Waveguide dispersion. Dispersion of polarization modes. Total dispersion. | 2 | 2 | PC-1.2, PC- 2.1, PC-2.2 |
| **1.4** | **Lecture** **4.** **Nonlinear optical effects in fiber light guides. Fiber optic sensors.** **(Lec).** Polarization of a dielectric in an electric field. Media with quadratic and cubic optical nonlinearity. The equation of nonlinear waves. Optical solitons. Forced Raman scattering. | 2 | 2 | PC-1.2, PC- 2.1, PC-2.2 |
| **1.5** | **Lecture** **5.** **Interaction of optical radiation with solids.** **(Lec).** The main parameters and characteristics of the interaction of radiation with matter. Types of radiation absorption mechanisms. Physical phenomena at various types of radiation absorption: intrinsic and impurity absorption in semiconductors, direct and indirect transitions, absorption by free carriers, lattice absorption. Intra- zone transitions. | 2 | 2 | PC-1.2, PC- 2.1, PC-2.2 |

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| **1.6** | **Lecture** **6.** **Photovoltaic phenomena in semiconductors and semiconductor devices. (Lec).** The main parameters characterizing the change in the state of matter during radiation absorption are: relaxation times of concentrations of nonequilibrium charge carriers, the quantum yield of the internal photoelectric effect. Kinetics of concentrations of nonequilibrium charge carriers. Intrinsic and impurity photoconductivity of semiconductors, direct and indirect transitions, photoconductivity relaxation time, photoconductivity gain. | 2 | 2 | PC-2.1, PC-2.2 |
| **1.7** | **Lecture** **7.** **Optical information technologies. (Lec).** Theory of systems and transformations in optics. Holographic storage devices and optical memory. Optical information processing. Integral transformations and their computer (FFT) and optical lens implementations. Digital holography. Computer optics. Hybrid optical-computer systems for processing and transmitting information and their application in radar, aerospace sensing of ground objects, nuclear physics, biology, etc. | 2 | 2 | PC-1.2, PC- 2.1, PC-2.2 |
| **1.8** | **Lecture** **8.** **Optical computers** **(Lec).** Processors for improving image quality, recognition and data processing. Mesooptics and super-resolution. Optical systems with feedback. Adaptive optics. Multistable optical elements. Optical neuropodic information processing systems. Fundamental physical limits of miniaturization of computer systems. Quantum computers and nanotechnology. Purely optical and hybrid computer systems for image processing and multidimensional data arrays. | 2 | 2 | PC-1.2, PC- 2.1, PC-2.2 |
| **1.9** | **Performing practical tasks (Pr).** PR 1. Basic terms and concepts of optical materials science. | 2 | 2 | PC-1.2, PC-2.1 |
| **1.10** | **Performing practical tasks (Pr).** PR 2. Classification of optical glasses. Methods of forming the refractive index profile in gradient optics elements. | 2 | 2 | PC-1.2, PC-2.1 |
| **1.11** | **Performing practical tasks (Pr).** PR 3. Single-mode and multimode fiber light guides. | 2 | 2 | PC-1.2, PC-2.1 |
| **1.12** | **Performing practical tasks (Pr).** PR 4. Active dielectrics. Generation of the second optical harmonic. | 2 | 2 | PC-1.2, PC-2.1 |

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| **1.13** | **Performing practical tasks (Pr).** PR 5. Photovoltaic effects in semiconductors. Barrier type of photo EMF. Other types of photo EMF, their disadvantages and advantages. | 2 | 2 | PC-1.2, PC-2.1 |
| **1.14** | **Performing practical tasks (Pr).** PR 6. Photo effects in semiconductors. Generation of optical radiation by solids. The principle of operation of the laser at the p-n junction. | 2 | 2 | PC-1.2, PC-2.1 |
| **1.15** | **Performing practical tasks (Pr).** PR 7. Holography. Methods of digital holography. | 2 | 2 | PC-1.2, PC-2.1 |
| **1.16** | **Performing practical tasks (Pr).** PR 8. Adaptive optics. | 2 | 2 | PC-1.2, PC-2.1 |
| **1.17** | **Performing practical tasks (Pr).** PR 9. Advantages of optical technologies. The first optical computers. | 2 | 2 | PC-1.2, PC-2.1 |
| **1.18** | **Oral interview (Pr).** Conducting a survey based on the materials of the lecture | 2 | 2 | PC-1.2, PC- 2.1, PC-2.2 |
| **1.19** | **Oral interview (Pr).** Conducting a survey based on the materials of the lecture | 2 | 2 | PC-1.2, PC- 2.1, PC-2.2 |
| **1.20** | **Oral interview (Pr).** Conducting a survey based on the materials of the lecture | 2 | 2 | PC-1.2, PC- 2.1, PC-2.2 |
| **1.21** | **Oral interview (Pr).** Conducting a survey based on the materials of the lecture | 2 | 2 | PC-1.2, PC- 2.1, PC-2.2 |
| **1.22** | **Oral interview (Pr).** Conducting a survey based on the materials of the lecture | 2 | 2 | PC-1.2, PC- 2.1, PC-2.2 |
| **1.23** | **Oral interview (Pr).** Conducting a survey based on the materials of the lecture | 2 | 2 | PC-1.2, PC- 2.1, PC-2.2 |
| **1.24** | **Oral interview (Pr).** Conducting a survey based on the materials of the lecture | 2 | 2 | PC-1.2, PC- 2.1, PC-2.2 |
| **1.25** | **Oral interview (Pr).** Conducting a survey based on the materials of the lecture | 2 | 2 | PC-1.2, PC- 2.1, PC-2.2 |
| **1.26** | **Defense of essays** **(Pr).** Defense of essays | 2 | 2 | PC-1.2, PC- 2.1, PC-2.2 |
| **1.27** | **Defense of essays** **(Pr).** Defense of essays | 2 | 2 | PC-1.2, PC- 2.1, PC-2.2 |
| **1.28** | **Defense of essays** **(Pr).** Defense of essays | 2 | 2 | PC-1.2, PC- 2.1, PC-2.2 |
| **1.29** | **Defense of essays** **(Pr).** Defense of essays | 2 | 2 | PC-1.2, PC- 2.1, PC-2.2 |
| **1.30** | **Defense of essays** **(Pr).** Defense of essays | 2 | 2 | PC-1.2, PC- 2.1, PC-2.2 |
| **1.31** | **Defense of essays** **(Pr).** Defense of essays | 2 | 2 | PC-1.2, PC- 2.1, PC-2.2 |
| **1.32** | **Solution of the control work (Pr).** Security questions for the section. | 2 | 2 | PC-1.2, PC- 2.1, PC-2.2 |
| **1.33** | **students do their home written work (essay, abstract) (IWS).** Writing essays | 2 | 40 | PC-1.2, PC- 2.1, PC-2.2 |
| **1.34** | **Preparation for classroom classes (IWS).** Repetition of lecture and practical materials | 2 | 40 | PC-1.2, PC- 2.1, PC-2.2 |

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| **2. Intermediate certification (exam)** | | | | | | |
| **2.1** | **Preparation for the intermediate certification (Exam).** | | 2 | 33,65 | PC-1.2, PC- 2.1, PC-2.2 | |
| **2.2** | **Contact work with the teacher during the intermediate certification (CWC).** | | 2 | 2,35 | PC-1.2, PC- 2.1, PC-2.2 | |
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| **5. EVALUATION MATERIALS** | | | | | | |
| **5.1. List of competencies** | | | | | | |
| List of competencies, the development of which the study of the discipline is aimed at «Optical materials and optical operation for information technologies», with an indication of the results of their formation in the process of mastering the educational program, presented in paragraph 3 of this work program | | | | | | |
| **5.2. Typical control questions and tasks** | | | | | | |
| 1. Varieties of optical materials. Classification of properties of optical materials.  2. The complex nature of the optical constants - the dielectric constant and the  refractive index. The physical nature of optical constants.  3. Quantitative characteristics of the passage of a monochromatic beam through a  plate of optical material. The Lambert-Booger law. Behr's law.  4. Types and mechanisms of absorption in various spectral ranges.  5.The main optical characteristics of glasses in the range of their transparency. Normal and abnormal variances.  6.Refraction: specific refraction, molar refraction, Cauchy formula.  7.The main optical characteristics used in photonics: the main refractive index, average dispersion, Abbe number, partial dispersion.  8. Methods of obtaining polarized radiation.  9. Materials for optical parts of polarizing devices.  10. Artificial anisotropy.  11. Rotation of the polarization plane.  12. Interference of polarized rays.  13. Devices for the analysis of polarized radiation.  14. Polarizing equipment.  15. Photoelectric measuring microscopes.  16. Photovoltaic autocollimators.  17. Raster measuring devices.  18. The device of scanning microscopes.  19. Principles of the device of colorimetric devices.  20. The content of GOST for colorimetric measurements.  21. The dispersion equation of a planar waveguide.  22. Materials of integrated optics.  23. Coupled optical waveguides.  24. Propagation of light waves in periodic structures  25.The concept of a nonlinear optical medium and the magnitude of the intensity of the light field necessary for the manifestation of nonlinear optical properties of the medium.  26. Expression for the permittivity of a medium with quadratic  nonlinearity and possible nonlinear optical effects in such a medium.  27. The concept of the lifetime of nonequilibrium charge carriers, the rate of generation, the rate of recombination of charge carriers. Mechanisms of photoconductivity.  28. Photoconductivity of a semiconductor. Intrinsic and impurity photoconductivity.  29. Kinetics of charge carrier concentrations under illumination. Determination of semiconductor parameters by the kinetic curve of photoconductivity. | | | | | | |
| **5.3. Fund of evaluation Materials** | | | | | | |

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| A complete list of evaluation materials is provided in the Appendix 1. | | | | | |
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| **6. MATERIAL, TECHNICAL, EDUCATIONAL AND METHODOLOGICAL SUPPORT OF THE DISCIPLINE (MODULE)** | | | | | |
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| **6.1. MATERIAL AND TECHNICAL SUPPORT OF THE DISCIPLINE (МОДУЛЯ)** | | | | | |
| **Name of premises** | | | | **List of main equipment** | |
| Classroom for lectures and seminars, group and individual consultations, ongoing monitoring and intermediate certification | | | | Multimedia equipment, specialized furniture, sets of demonstration equipment and educational and visual aids that provide thematic illustrations. | |
| A room for independent work of students | | | | Computer equipment with the ability to connect to the Internet and provide access to the electronic information and educational environment of the organization. | |
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| **6.2. LIST OF SOFTWARE** | | | | | |
| 1. |  | Microsoft Windows. Contract No. 32009183466 from 02.07.2021. | | | |
| 2. |  | Microsoft Office. Contract No. 32009183466 from 02.07.2021. | | | |
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| **6.3. RECOMMENDED LITERATURE** | | | | | |
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| **6.3.1. Basic literature** | | | | | |
| 1. |  | Guzhov V. I., Il'inyh S. P. Opticheskie izmereniya. Komp'yuternaya interferometriya [Electronic resource]:Uchebnoe posobie dlya vuzov. - Moscow: YUrajt, 2021. - 258 s – Access mode: https://urait.ru/bcode/472112 | | | |
| 2. |  | Patrusheva T. N. Sensorika. Sovremennye tekhnologii mikro- i nanoelektroniki:Uchebnoe osobie dlya vuzov. - M.: INFRA-M, 2016. - 260 s. | | | |
| 3. |  | Sarina M. P., Holyavko V. N. Volnovaya i kvantovaya optika [Electronic resource]:uchebnoe posobie. - Novosibirsk: NGTU, 2019. - 124 s. – Access mode: https://e.lanbook.com/book/152332 | | | |
| 4. |  | Kirillovskij V. K. Sovremennye opticheskie issledovaniya i izmereniya [Electronic resource]:. - Sankt-Peterburg: Lan', 2021. - 304 s. – Access mode: https://e.lanbook.com/book/167816 | | | |
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| **6.3.2. Additional literature** | | | | | |
| 1. |  | Listvin A. V., Listvin V. N., SHvyrkov D. V. Opticheskie volokna dlya linij svyazi:. - M.: LESARart, 2003. - 288 s. | | | |
| 2. |  | Friman R. L. Volokonno-opticheskie sistemy svyazi:Per. s angl.. - M.: Tekhnosfera, 2007. - 511 s. | | | |
| 3. |  | Rozensher E., Vinter B. Optoelektronika:Per. s fr.. - M.: Tekhnosfera, 2004. - 589 s. | | | |
| 4. |  | Korovchenko, Uskov, Potapov Optoelektronika [Electronic resource]:. - Voronezh: Izdatel'skij dom VGU, 2015. - 32 – Access mode: https://lib.rucont.ru/efd/437114 | | | |
| 5. |  | Olifer V. G., Olifer N. A. Komp'yuternye seti. Principy, tekhnologii, protokoly:. - SPb.: Piter, 2011. - 943 s. | | | |
| 6. |  | Holevo A. S. Vvedenie v kvantovuyu teoriyu informacii [Electronic resource]:. - , 2002. - 126 s. – Access mode: http://library.mirea.ru/secret/mm\_09018.djvu | | | |
| 7. |  | SHreder G., Trejber H. Tekhnicheskaya optika:Per. s nem.. - M.: Tekhnosfera, 2006. - 424 s. | | | |
| 8. |  | Andreev A. N., Gavrilov E. V., Ishanin G. G., i dr. Opticheskie izmereniya:Ucheb. posobie dlya vuzov. - M.: Logos, 2008. - 415 s. | | | |
| 9. |  | Zajcev S.A., Gribanov D.D., Tolstov A.N.,Merkulov R.V. Kontrol'no-izmeritel'nye pribory i instrumenty:. - M.: Akademiya: ProfObrIzdat, 2002. - 464 s. | | | |

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| **6.4. RECOMMENDED LIST OF MODERN PROFESSIONAL DATABASES AND INFORMATION REFERENCE SYSTEMS** | | | | |
| 1. |  | Materials Science Information Portal http://www.materialstoday.com | | |
| 2. |  | Website of the PTI Department of Nanoelectronics https://fks.mirea.ru | | |
| 3. |  | Database Web of Science  http://www.webofknowledge.com | | |
| 4. |  | News and analytical portal "Vremya elektroniki "  http://www.russianelectronics.ru | | |
| 5. |  | Journal «Nano- and Microsystem Technology»  http://www.microsystems.ru | | |
| 6. |  | Elektronika NTB - scientific and technical journal  http://www.electronics.ru | | |
| 7. |  | Information and reference portal of scientific publications of domestic and foreign authors «Google Academy»  https://www.scholar.google.ru | | |
| 8. |  | Russian Technological Journal  https://www.rtj.mirea.ru | | |
| 9. |  | Magazine portal of the A.F. Ioffe Institute of Physics and Technology  https://www.journals.ioffe.ru | | |
| 10. |  | Information portal of the International Citation System Scopus  https://www.scopus.com | | |
| 11. |  | Information portal of the International Citation System «Web of Science”  https://www.apps.webofknowledge.com | | |
| 12. |  | Foundation for the Promotion of Innovation  http://www.fasie.ru | | |
| 13. |  | Ministry of Science and Higher Education of the Russian Federation  https://www.minobrnauki.gov.ru | | |
| 14. |  | Scientific Electronic Library http://www.elibrary.ru | | |
| 15. |  | Information portal of the Russian Science Foundation http://www.rscf.ru | | |
| 16. |  | Russian Foundation for Basic Research https://www.rfbr.ru | | |
| 17. |  | Nanometer - Nanotechnology community http://www.nanometer.ru | | |
| 18. |  | NanoNewsNet.ru- non-commercial on-line publication dedicated to the nanoindustry http://www.old.nanonewsnet.ru | | |
| 19. |  | Electronic fund of legal and regulatory technical documentation Tekhnoexpert http://www.docs.cntd.ru | | |
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| **6.5. METHODICAL INSTRUCTIONS FOR STUDENTS STUDYING THE DISCIPLINE (MODULE)** | | | | |
| The student’s independent work is aimed at preparing for academic classes and at developing knowledge, skills and abilities provided for in the discipline program.  In accordance with the curriculum, the discipline may include Lectures, practical classes and Laboratory work, as well as the execution and defense of a course project (work). Successful study of the discipline requires attending all types of classes, completing teacher assignments and familiarization with basic and additional literature. Depending on the activities provided for in the curriculum and section 4 of this program, the student chooses methodological guidelines for independent work from the ones listed below. | | | | |

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| When preparing for lecture classes, students need to:  before the next lecture, it is necessary to review the summary of the material of the previous Lectures. If you have difficulties in perceiving the material, you should refer to the main literary sources. If it was not possible to understand the material again, then contact the lecturer (according to the schedule of his consultations) or the teacher in practical classes.  Practical classes complete the study of the most important topics of the discipline. They serve to consolidate the studied material, develop the skills and abilities of preparing reports, messages, gaining experience in oral public speeches, conducting discussions, argumentation and defending the propositions put forward, as well as to monitor the degree of readiness of students in the discipline being studied by the teacher.  When preparing for a practical lesson, students have the opportunity to use the advice of a teacher.  When preparing for practical classes, students need to:  bring with you the literature recommended by the teacher for a specific lesson;  before the next practical lesson on the recommended literary sources, work out the theoretical material corresponding to the topic of the lesson;  at the beginning of classes, ask the teacher questions about the material that caused difficulties in understanding and mastering it when solving tasks set for independent solution;  during the seminar, give specific, clear answers to the substance of the questions;  at the training session, bring each task to the final solution, demonstrate an understanding of the calculations (analyses, situations), in case of difficulties, contact the teacher.  Students who have missed classes (regardless of the reasons), who do not have a written solution to problems or are not prepared for this practical lesson, are recommended to come to the teacher’s consultation no later than 2 weeks and report on the topic studied in the lesson.  The methodological guidelines necessary for studying and passing the discipline are given as part of the educational program. | | |
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| **6.6. METHODOLOGICAL RECOMMENDATIONS FOR THE TRAINING OF PERSONS WITH LIMITED HEALTH OPPORTUNITIES AND THE DISABLED** | | |
| The development of the discipline by students with disabilities can be organized both jointly with other students and in separate groups. Special conditions are assumed for students with disabilities to receive education.  The teaching staff gets acquainted with the psychological and physiological characteristics of students with disabilities and persons with disabilities, individual rehabilitation programs for the disabled (if available). If necessary, additional teaching support is provided by tutors, psychologists, social workers, trained assistants.  In accordance with the methodological recommendations of the Ministry of Education and Science of the Russian Federation (approved April 8, 2014 N AK-44/05vn), the course is supposed to use socially active and reflective teaching methods, technologies of socio-cultural rehabilitation in order to assist in establishing full-fledged interpersonal relationships with other students, creating a comfortable psychological climate in the student group. Selection and development of educational materials are made taking into account the provision of material in various forms: auditory, visual, using special technical means and information systems.  Mediamaterials should also be used and adapted taking into account the individual characteristics of the training of persons with disabilities.  The development of the discipline by persons with disabilities is carried out using general and special purpose teaching tools (personal and collective use). Material and technical support provides for the adaptation of classrooms to the needs of persons with disabilities.  The form of certification for students with disabilities is established taking into account individual psychophysical characteristics. For students with HIA, an accessible form of assignment of assessment tools is provided, namely: | | |

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| - in printed or electronic form (for persons with disorders of the musculoskeletal system);  - in printed or electronic form with enlarged font and contrast (for persons with hearing, speech, vision impairments);  - reading the task aloud by the assistant (for visually impaired persons).  Students with disabilities have increased time to prepare answers to control questions. For such students, an accessible form of providing answers to tasks is provided, namely:  - written on paper or a set of answers on a computer (for persons with hearing and speech impairments);  - choosing an answer from possible options using the services of an assistant (for people with musculoskeletal disorders);  - oral interview (for persons with visual impairments, musculoskeletal system).  If necessary, for students with disabilities, the procedure for evaluating learning outcomes can be carried out in several stages. |

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| Federal State Budget Educational Institution of Higher Education  «MIREA – Russian Technological University» | | | | | | | | | | | | | | | | | | | | | |
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| Working program of the discipline (module) | | | | | | | | | | | | | | | | | | | | | |
| **Research and development management** | | | | | | | | | | | | | | | | | | | | | |
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|  | Department leading the training | | | | | |  |  | **Department of Nanoelectronics** | | | | | | | | | | | | |
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|  | Direction of training | | | | | | |  | **11.04.04 Electronics and nanoelectronics** | | | | | | | | | | | | |
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|  | Profile | | | | | | |  | **Engineering of modern materials for information technology, renewable energy and sensing** | | | | | | | | | | | | |
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|  | Qualification | | | | |  |  |  | **Master** | | | | | | | | | | | | |
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|  | Form of education | | | | |  |  |  | **Full-time** | | | | | | | | | |  |  |  |
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|  | Total labor intensity | | | |  |  |  |  | **3 credits** | | | | | | | | | |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| **Distribution of discipline hours and forms of intermediate certification by semesters** | | | | | | | | | | | | | | | | | | | | | |
| Semester | | Credits | Distribution of hours | | | | | | | | | | | | | | | Forms of intermediate attestation | | |  |
| Total | Lectures | | | | Laboratory work | | | Practical classes | Independent work of students | | Contact work during practice and (or) certification | | | Control of training |  |
| 1 | | 3 | 108 | 16 | | | | 0 | | | 0 | 74 | | 0,25 | | | 17,75 | Test | | |  |
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| The program was made by: |  |  |  |  |
|  |  |  |  |  |
| *Doctor of Science in Physico-mathematical Sciences, Professor, E. Mishina \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_* | | | | |
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| Working program of the discipline | | |  |  |
| **Research and development management** | | | | |
|  |  |  |  |  |
| it is developed in accordance with FSES HE: | | |  |  |
| Federal State Educational Standard of Higher Education - Magistracy in the Direction of training 11.04.04 Electronics and nanoelectronics (order of the Ministry of Science and Higher Education of the Russian Federation from 22.09.2017. № 959) | | | | |
|  |  |  |  |  |
| it is based on the curriculum: | | |  |  |
| Direction of training: 11.04.04 Electronics and nanoelectronics  Profile: «Engineering of modern materials for information technology, renewable energy and sensing» | | | | |
|  |  |  |  |  |
| The working program was approved at the meeting of the department | | | | |
| **Department of Nanoelectronics** | | | | |
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| Minutes of meeting from 02.03.2021 № 3  Head of the Department A. Sigov \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ | | | | |

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| **Approval of the WPD for execution in the next academic year** | | | | |
|  |  |  |  |  |
| The working program was revised, discussed and approved for execution in the 2022-2023 academic year at a meeting of the department | | | | |
| **Department of Nanoelectronics** | | | | |
|  |  |  |  |  |
|  | Minutes of meeting from \_\_ \_\_\_\_\_\_\_\_\_\_ 2022. № \_\_  Head of the Department \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ | | | |
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| **Approval of the WPD for execution in the next academic year** | | | | |
|  |  |  |  |  |
| The working program was revised, discussed and approved for execution in the 2023-2024 academic year at a meeting of the department | | | | |
| **Department of Nanoelectronics** | | | | |
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|  | Minutes of meeting from \_\_ \_\_\_\_\_\_\_\_\_\_ 2023. № \_\_  Head of the Department \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ | | | |
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| **Approval of the WPD for execution in the next academic year** | | | | |
|  |  |  |  |  |
| The working program was revised, discussed and approved for execution in the 2024-2025 academic year at a meeting of the department | | | | |
| **Department of Nanoelectronics** | | | | |
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|  | Minutes of meeting from \_\_ \_\_\_\_\_\_\_\_\_\_ 2024. № \_\_  Head of the Department \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ | | | |
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| **Approval of the WPD for execution in the next academic year** | | | | |
|  |  |  |  |  |
| The working program was revised, discussed and approved for execution in the 2025-2026 academic year at a meeting of the department | | | | |
| **Department of Nanoelectronics** | | | | |
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|  | Minutes of meeting from \_\_ \_\_\_\_\_\_\_\_\_\_ 2025. № \_\_  Head of the Department \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ | | | |
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| **1. OBJECTIVES OF MASTERING THE DISCIPLINE (MODULE)** | | | | | |
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| The discipline «Research and development management» aims to contribute to the formation of students’ competencies, provided by this work program in accordance with the requirements of FSES HE in the direction of training 11.04.04 Electronics and nanoelectronics, taking into account the specifics of the profile – «Engineering of modern materials for information technology, renewable energy and sensing». | | | | | |
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| **2. PLACE OF DISCIPLINE (MODULE) IN THE STRUCTURE OF THE EDUCATIONAL PROGRAM** | | | | | |
|  | Direction of training: |  | 11.04.04 Electronics and nanoelectronics | | |
|  |
|  | Profile: |  | Engineering of modern materials for information technology, renewable energy and sensing | | |
|  |  |  |
|  | Block: |  | Disciplines (modules) | | |
|  |  |  |
|  | Part: |  | Mandatory part | | |
|  |  |  |
|  | Total labor intensity: |  | 3 credits (108 academic hours). | | |
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| **3. THE STUDENT’S COMPETENCIES FORMED AS A RESULT OF MASTERING THE DISCIPLINE (MODULE)** | | | | | |
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| As a result of mastering the practice, the student must master the following competencies: | | | | | |
| **UC-2** - Capable to manage a project at all stages of its life cycle | | | | | |
| **GPC-2** - Capable to apply modern research methods, present and argumentatively defend the results of the work performed | | | | | |
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| **PLANNED RESULTS OF TRAINING IN THE DISCIPLINE (MODULE), CHARACTERIZING THE FORMATION OF COMPETENCIES** | | | | | |
|  |  |  |  |  |  |
| **UC-2 : Capable to manage a project at all stages of its life cycle** | | | | | |
|  |  |  |  |  |  |
| **UC-2.1: Forms a project task based on the problem posed, the way to solve it through the implementation of project management** | | | | | |
| **To know:** | | | | | |
| - modern sources of scientific information, in particular Russian and international databases of scientific journals and patent sources; methods of searching and analyzing sources that substantiate methods and approaches to solving the problem, its novelty, relevance and significance. | | | | | |
| **Be able to:** | | | | | |
| - based on the selected sources, set a project task, justify its novelty and significance, choose adequate methods and approaches to solving the problem, analyze the problem, highlighting the stages of its solution. | | | | | |
| **Possess:** | | | | | |
| - methods of solving tasks through project management | | | | | |
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| **UC-2.2: Develops a project concept within the framework of the designated problem and a project implementation plan, taking into account possible implementation risks and opportunities to eliminate them** | | | | | |
| **To know:** | | | | | |
| - methods of formulation of goals, tasks, problems, risks and significance of projects, stages of the project life cycle; stages of project development and implementation; methods of project development and management. | | | | | |

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| **Be able to:** | | |
| - to develop a project taking into account the risk analysis of its implementation, to determine the target stages, main directions and expected results of work; to organize the control of the project implementation taking into account the possible risks | | |
| **Possess:** | | |
| - skills of project development and management, skills of monitoring the implementation of the work plan and achieving expected results; skills of adjusting the plan and justifying adjustments in case of deviations in the course of project implementation; skills of creating applications for participation in competitions, skills of registration and submission of project reporting documentation | | |
|  |  |  |
| **GPC-2 : Capable to apply modern research methods, present and argumentatively defend the results of the work performed** | | |
| **GPC-2.1: Applies modern research methods in the field of electronics** | | |
| **To know:** | | |
| - methods of conducting a comparative analysis of research methods in a given direction in the field of electronics based on various sources | | |
| **Be able to:** | | |
| - conduct a comparative analysis of research methods in a given direction in the field of electronics based on various sources; the choice of an adequate research method based on the analysis of sources, as well as the analysis of available resources and infrastructure | | |
| **Possess:** | | |
| - skills of choosing an adequate research method in a given direction in the field of electronics based on the analysis of sources, as well as analysis of available resources and infrastructure | | |
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| **GPC-2.2: Is able to present the results of work** | | |
| **To know:** | | |
| - modern methods of research of materials and products of electronics and nanoelectronics and ways of presenting the results of research in this area | | |
| **Be able to:** | | |
| - present and defend the results of the work performed in a reasoned manner | | |
| **Possess:** | | |
| - skills of organizing and conducting research by research teams of various levels, presentation and reasoned defense of the results of the work performed | | |
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| **AS A RESULT OF STUDYING THE DISCIPLINE (MODULE), THE STUDENT MUST** | | |
| **To know:** | | |
| - methods of formulation of goals, tasks, problems, risks and significance of projects, stages of the project life cycle; stages of project development and implementation; methods of project development and management. | | |
| - modern methods of research of materials and products of electronics and nanoelectronics and ways of presenting the results of research in this area | | |
| - methods of conducting a comparative analysis of research methods in a given direction in the field of electronics based on various sources | | |
| - modern sources of scientific information, in particular Russian and international databases of scientific journals and patent sources; methods of searching and analyzing sources that substantiate methods and approaches to solving the problem, its novelty, relevance and significance. | | |
| **Be able to:** | | |

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| - conduct a comparative analysis of research methods in a given direction in the field of electronics based on various sources; the choice of an adequate research method based on the analysis of sources, as well as the analysis of available resources and infrastructure | | | | | | |
| - to develop a project taking into account the risk analysis of its implementation, to determine the target stages, main directions and expected results of work; to organize the control of the project implementation taking into account the possible risks | | | | | | |
| - present and defend the results of the work performed in a reasoned manner | | | | | | |
| - based on the selected sources, set a project task, justify its novelty and significance, choose adequate methods and approaches to solving the problem, analyze the problem, highlighting the stages of its solution. | | | | | | |
| **Possess:** | | | | | | |
| - skills of organizing and conducting research by research teams of various levels, presentation and reasoned defense of the results of the work performed | | | | | | |
| - methods of solving tasks through project management | | | | | | |
| - skills of project development and management, skills of monitoring the implementation of the work plan and achieving expected results; skills of adjusting the plan and justifying adjustments in case of deviations in the course of project implementation; skills of creating applications for participation in competitions, skills of registration and submission of project reporting documentation | | | | | | |
| - skills of choosing an adequate research method in a given direction in the field of electronics based on the analysis of sources, as well as analysis of available resources and infrastructure | | | | | | |
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| **4. STRUCTURE AND CONTENT OF THE DISCIPLINE (MODULE)** | | | | | | |
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| During the training sessions, the organization ensures the development of students’ teamwork skills, interpersonal communication, decision-making and leadership qualities. | | | | | | |
| **Code** | **Name of sections and topics /type of classes/** | | **Semester** | **Academic Hours** | **Competencies** | |
| **1. Research and development management в электронике** | | | | | | |
| **1.1** | **Lecture** **1.** **General issues of methodology and organization of scientific research.** **(Lec).** Science as a type of human activity. Classification of sciences. The concept of the research method. General scientific methods and methods of private sciences. Classification of scientific research (theoretical and experimental research; fundamental and applied research). Types of research activities (R&D).  Standards of scientific activity. Reproducibility. Historical evolution of standards of scientific experimentation. Methodology of scientific research. | | 1 | 2 | GPC-2.2 | |
| **1.2** | **Homework (IWS).** IWS 1. Control questions for the lecture1 | | 1 | 4 | UC-2.1, UC- 2.2, GPC-2.1, GPC-2.2 | |

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| **1.3** | **Lecture** **2.** **Organizational structure of science management bodies and research organizations. Functions of various departments. (Lec).** Ministry of Science of Higher Education of the Russian Federation. Departments of the Ministry. Russian Academy of Sciences. The Higher Attestation Commission (HAC) and the procedure for awarding academic degrees. Science in scientific institutes and universities. Directorate of the Science Institution. Research department. Institute, department, laboratory. MEGA-science institutions. Academic exchange programs. International cooperation in science. The need for an international scientific discussion. | 1 | 2 | UC-2.2 |
| **1.4** | **Homework (IWS).** IWS 2. Control questions for the lecture2 | 1 | 4 | UC-2.1, UC- 2.2, GPC-2.1, GPC-2.2 |
| **1.5** | **Lecture** **3.** **Sources determining the directions of science development.** **(Lec).** The "Science" program. The Law on Science. Presidential decrees. Road maps. | 1 | 2 | UC-2.1 |
| **1.6** | **Homework (IWS).** IWS 3. Control questions for the lecture3 | 1 | 4 | UC-2.1, UC- 2.2, GPC-2.1, GPC-2.2 |
| **1.7** | **Lecture** **4.** **Financing of science (Lec).** Financing of science: programs, grants. Russian Foundation for Basic Research (RFBR). Russian Science Foundation (RSF). Resolution p.220 - Megagrants. Federal-targeted programs. Foundation for Advanced Research. Foundation for the Promotion of Innovation. Features of contests of various funds. | 1 | 2 | UC-2.1 |
| **1.8** | **Homework (IWS).** IWS 4. Control questions for the lecture4 | 1 | 4 | UC-2.1, UC- 2.2, GPC-2.1, GPC-2.2 |
| **1.9** | **Lecture** **5.** **Information basis of scientific research. Algorithm of scientific research (Lec).** Information basis of scientific research. RSCI. Scopus. Science networks. The algorithm of scientific research. Relevance of the study. Setting goals and objectives of the study. Forming a research plan and dividing it into stages. Conducting research as part of the algorithm. Identification of the features of the studied effects. Processing of research results. Discussion of the results. Revision and adjustment of the research plan. Formulation of conclusions. Prospects for the practical application of the results. Formation of technical specifications for the implementation of R&D. | 1 | 2 | UC-2.1, UC- 2.2, GPC-2.2 |

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| **1.10** | **Homework (IWS).** IWS 5. Study of the tender documentation of one of the scientific foundations of the Russian Federation. Preparation of a scientific project in accordance with the competition documentation. | 1 | 20 | UC-2.1, UC- 2.2, GPC-2.1, GPC-2.2 |
| **1.11** | **Lecture** **6.** **Fundamentals of project management (Lec).** Definition of Project. The role of the project manager. The principles of project management and the main terms used in project management. Stages of the project. Formation of a team of performers, distribution of obligations. Organizational structure. Interaction with the organization's management and administration. Accounting and control systems. Co-executors of the project. Comparative analysis of project costs and results. Features of scientific and technical results. Determining the scope and timing of the project. Conditions and limitations of the project. Project performance indicators. Types of resources. Budget planning. Classification of project costs. Accounting of financial expenses. Financial statements. | 1 | 2 | UC-2.1, UC- 2.2, GPC-2.1, GPC-2.2 |
| **1.12** | **Homework (IWS).** IWS 6. Control questions for the lecture6 | 1 | 4 | UC-2.1, UC- 2.2, GPC-2.1, GPC-2.2 |
| **1.13** | **Lecture** **7.** **Publication and patenting. Legal protection of research results.** **(Lec).** Publication of an article in a scientific journal. Principles of choosing a journal for publication. Publication of research results at conferences. Fundamentals of legislation in terms of patenting. Patent search. What results cannot be patented (features of patenting in Russia and abroad). Preparation of the application. Interaction with patent organizations. Patent information databases. Algorithm for publishing research results. International citation systems and methods of working with them. | 1 | 2 | UC-2.1, GPC- 2.1 |
| **1.14** | **Homework (IWS).** IWS 7. Control questions for the lecture7 | 1 | 2 | UC-2.1, UC- 2.2, GPC-2.1, GPC-2.2 |
| **1.15** | **Lecture** **8.** **Research and development management in enterprises. Preparation of a master's thesis (Lec).** Research and development management at enterprises: on the example of specific enterprises of the Russian Federation. Requirements for the design of a master's thesis. Topics and content of sections. References and citations. Interaction with the supervisor. b to the defense, interaction with the reviewer. The pre-defense procedure – why it is needed, what to prepare for, pitfalls. Protection and actions after it. | 1 | 2 | UC-2.1, UC- 2.2, GPC-2.1, GPC-2.2 |

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| **1.16** | | | **Homework (IWS).** IWS 8. Cross-reviewing projects prepared by colleagues | | | 1 | 20 | UC-2.1, UC- 2.2, GPC-2.1, GPC-2.2 | |
| **1.17** | | | **Preparation for classroom classes (IWS).** Preparation for lectures | | | 1 | 12 | UC-2.1, UC- 2.2, GPC-2.1, GPC-2.2 | |
| **2. Intermediate certification (Test)** | | | | | | | | | |
| **2.1** | | | **Preparation for the intermediate certification (Test).** | | | 1 | 17,75 | UC-2.1, UC- 2.2, GPC-2.1, GPC-2.2 | |
| **2.2** | | | **Contact work with the teacher during the intermediate certification (CWC).** | | | 1 | 0,25 | UC-2.1, UC- 2.2, GPC-2.1, GPC-2.2 | |
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| **5. EVALUATION MATERIALS** | | | | | | | | | |
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| **5.1. List of competencies** | | | | | | | | | |
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| List of competencies, the development of which the study of the discipline is aimed at «Research and development management», with an indication of the results of their formation in the process of mastering the educational program, presented in paragraph 3 of this work program | | | | | | | | | |
| **5.2. Typical control questions and tasks** | | | | | | | | | |
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| 1. The procedure for awarding scientific degrees and titles in Russia and abroad.  2. Name the difference and similarity of the organization of fundamental and applied research.  3. List the types of research activities.  4. List the rights and obligations of the project manager and executors.  5. What are the main stages of the project implementation | | | | | | | | | |
| **5.3. Fund of evaluation Materials** | | | | | | | | | |
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| A complete list of evaluation materials is provided in the Appendix 1. | | | | | | | | | |
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| **6. MATERIAL, TECHNICAL, EDUCATIONAL AND METHODOLOGICAL SUPPORT OF THE DISCIPLINE (MODULE)** | | | | | | | | | |
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| **6.1. MATERIAL AND TECHNICAL SUPPORT OF THE DISCIPLINE (МОДУЛЯ)** | | | | | | | | | |
| **Name of premises** | | | | | **List of main equipment** | | | | |
| Classroom for lectures and seminars, group and individual consultations, ongoing monitoring and intermediate certification | | | | | Multimedia equipment, specialized furniture, sets of demonstration equipment and educational and visual aids that provide thematic illustrations. | | | | |
| A room for independent work of students | | | | | Computer equipment with the ability to connect to the Internet and provide access to the electronic information and educational environment of the organization. | | | | |
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| **6.2. LIST OF SOFTWARE** | | | | | | | | | |
| 1. |  | Microsoft Windows. Contract No. 32009183466 from 02.07.2021. | | | | | | | |
| 2. |  | Microsoft Office. Contract No. 32009183466 from 02.07.2021. | | | | | | | |
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| **6.3. RECOMMENDED LITERATURE** | | | | | | | | | |
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| **6.3.1. Basic literature** | | | | | | | | | |

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| 1. |  | Sherstyuk N. E., Gladyshev I. V., Kuznecov V. V. Metodicheskie ukazaniya po vypolneniyu vypusknoj kvalifikacionnoj raboty magistra (magisterskoj dissertacii) [Electronic resource]:. - M.: RTU MIREA, 2021. - – Access mode: https://library.mirea.ru/secret/11062021/2714.iso | | |
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| **6.3.2. Additional literature** | | | | |
| 1. |  | Puzynya K. F., Kazancev A. K., Baryutin L. S. Organizaciya i planirovanie nauchnyh issledovanij i opytno-konstruktorskih razrabotok:Ucheb. posobie dlya inzh. -ekon. spec. vuzov. - M.: Vyssh. shk., 1989. - 222 s. | | |
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| **6.4. RECOMMENDED LIST OF MODERN PROFESSIONAL DATABASES AND INFORMATION REFERENCE SYSTEMS** | | | | |
| 1. |  | Website of the PTI Department of Nanoelectronics https://fks.mirea.ru | | |
| 2. |  | News and analytical portal "Vremya elektroniki "  http://www.russianelectronics.ru | | |
| 3. |  | Information and reference portal of scientific publications of domestic and foreign authors «Google Academy»  https://www.scholar.google.ru | | |
| 4. |  | Russian Technological Journal  https://www.rtj.mirea.ru | | |
| 5. |  | Information portal of the International Citation System Scopus  https://www.scopus.com | | |
| 6. |  | Information portal of the International Citation System «Web of Science”  https://www.apps.webofknowledge.com | | |
| 7. |  | Foundation for the Promotion of Innovation  http://www.fasie.ru | | |
| 8. |  | Ministry of Science and Higher Education of the Russian Federation  https://www.minobrnauki.gov.ru | | |
| 9. |  | Information portal of the Russian Science Foundation http://www.rscf.ru | | |
| 10. |  | Russian Foundation for Basic Research https://www.rfbr.ru | | |
| 11. |  | Information portal «Popular nanotechnologies» http://www.popnano.ru | | |
| 12. |  | Database Web of Science  http://www.webofknowledge.com | | |
| 13. |  | National Research Center «Kurchatov Institute»  http://www.kcsni.nrcki.ru | | |
| 14. |  | An international resource for the search and exchange of scientific publications  https://www.researchgate.net | | |
| 15. |  | Elektronika NTB - scientific and technical journal  http://www.electronics.ru | | |
| 16. |  | Scientific Electronic Library http://www.elibrary.ru | | |
| 17. |  | Electronic fund of legal and regulatory technical documentation Tekhnoexpert http://www.docs.cntd.ru | | |
| 18. |  | Consultant Plus http:// www.consultant.ru | | |
| 19. |  | Information and legal portal GARANT http:// www.garant.ru | | |
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| **6.5. METHODICAL INSTRUCTIONS FOR STUDENTS STUDYING THE DISCIPLINE (MODULE)** | | | | |
| The student’s independent work is aimed at preparing for academic classes and at developing knowledge, skills and abilities provided for in the discipline program.  In accordance with the curriculum, the discipline may include lectures, practical classes and laboratory work, as well as the execution and defense of a course project (work). | | | | |

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| Successful study of the discipline requires attending all types of classes, completing teacher assignments and familiarization with basic and additional literature. Depending on the activities provided for in the curriculum and section 4 of this program, the student chooses methodological guidelines for independent work from the ones listed below.  When preparing for lecture classes, students need to:  before the next lecture, it is necessary to review the summary of the material of the previous Lectures. If you have difficulties in perceiving the material, you should refer to the main literary sources. If it was not possible to understand the material again, then contact the lecturer (according to the schedule of his consultations) or the teacher in practical classes.  Practical classes complete the study of the most important topics of the discipline. They serve to consolidate the studied material, develop the skills and abilities of preparing reports, messages, gaining experience in oral public speeches, conducting discussions, argumentation and defending the propositions put forward, as well as to monitor the degree of readiness of students in the discipline being studied by the teacher.  When preparing for a practical lesson, students have the opportunity to use the advice of a teacher.  When preparing for practical classes, students need to:  bring with you the literature recommended by the teacher for a specific lesson;  before the next practical lesson on the recommended literary sources, work out the theoretical material corresponding to the topic of the lesson;  at the beginning of classes, ask the teacher questions about the material that caused difficulties in understanding and mastering it when solving tasks set for independent solution;  during the seminar, give specific, clear answers to the substance of the questions;  at the training session, bring each task to the final solution, demonstrate an understanding of the calculations (analyses, situations), in case of difficulties, contact the teacher.  Students who have missed classes (regardless of the reasons), who do not have a written solution to problems or are not prepared for this practical lesson, are recommended to come to the teacher’s consultation no later than 2 weeks and report on the topic studied in the lesson.  The methodological guidelines necessary for studying and passing the discipline are given as part of the educational program. | | |
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| **6.6. METHODOLOGICAL RECOMMENDATIONS FOR THE TRAINING OF PERSONS WITH LIMITED HEALTH OPPORTUNITIES AND THE DISABLED** | | |
| The development of the discipline by students with disabilities can be organized both jointly with other students and in separate groups. Special conditions are assumed for students with disabilities to receive education.  The teaching staff gets acquainted with the psychological and physiological characteristics of students with disabilities and persons with disabilities, individual rehabilitation programs for the disabled (if available). If necessary, additional teaching support is provided by tutors, psychologists, social workers, trained assistants.  In accordance with the methodological recommendations of the Ministry of Education and Science of the Russian Federation (approved April 8, 2014 N AK-44/05vn), the course is supposed to use socially active and reflective teaching methods, technologies of socio-cultural rehabilitation in order to assist in establishing full-fledged interpersonal relationships with other students, creating a comfortable psychological climate in the student group. Selection and development of educational materials are made taking into account the provision of material in various forms: auditory, visual, using special technical means and information systems.  Mediamaterials should also be used and adapted taking into account the individual characteristics of the training of persons with disabilities. | | |

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| The development of the discipline by persons with disabilities is carried out using general and special purpose teaching tools (personal and collective use). Material and technical support provides for the adaptation of classrooms to the needs of persons with disabilities.  The form of certification for students with disabilities is established taking into account individual psychophysical characteristics. For students with HIA, an accessible form of assignment of assessment tools is provided, namely:  - in printed or electronic form (for persons with disorders of the musculoskeletal system);  - in printed or electronic form with enlarged font and contrast (for persons with hearing, speech, vision impairments);  - reading the task aloud by the assistant (for visually impaired persons).  Students with disabilities have increased time to prepare answers to control questions. For such students, an accessible form of providing answers to tasks is provided, namely:  - written on paper or a set of answers on a computer (for persons with hearing and speech impairments);  - choosing an answer from possible options using the services of an assistant (for people with musculoskeletal disorders);  - oral interview (for persons with visual impairments, musculoskeletal system).  If necessary, for students with disabilities, the procedure for evaluating learning outcomes can be carried out in several stages. |

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| Federal State Budget Educational Institution of Higher Education  «MIREA – Russian Technological University» | | | | | | | | | | | | | | | | | | | | | |
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| Working program of the discipline (module) | | | | | | | | | | | | | | | | | | | | | |
| **Сomputer-aided design systems** | | | | | | | | | | | | | | | | | | | | | |
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|  | Department leading the training | | | | | |  |  | **Department of Nanoelectronics** | | | | | | | | | | | | |
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|  | Direction of training | | | | | | |  | **11.04.04 Electronics and nanoelectronics** | | | | | | | | | | | | |
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|  | Profile | | | | | | |  | **Engineering of modern materials for information technology, renewable energy and sensing** | | | | | | | | | | | | |
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| **Distribution of discipline hours and forms of intermediate certification by semesters** | | | | | | | | | | | | | | | | | | | | | |
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| Total | Lectures | | | | Laboratory work | | | Practical classes | Independent work of students | | Contact work during practice and (or) certification | | | Control of training |  |
| 2 | | 6 | 216 | 16 | | | | 0 | | | 64 | 82 | | 4,35 | | | 49,65 | Exam, Coursework | | |  |
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| The program was made by: |  |  |  |  |
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| *Ph.D. of Technical Sciences, Associate Professor, Pevtsov E.Ph. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_* | | | | |
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| Working program of the discipline | | |  |  |
| **Сomputer-aided design systems** | | | | |
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| it is developed in accordance with FSES HE: | | |  |  |
| Federal State Educational Standard of Higher Education - Magistracy in the Direction of training 11.04.04 Electronics and nanoelectronics (order of the Ministry of Science and Higher Education of the Russian Federation from 22.09.2017. № 959) | | | | |
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| it is based on the curriculum: | | |  |  |
| Direction of training: 11.04.04 Electronics and nanoelectronics  Profile: «Engineering of modern materials for information technology, renewable energy and sensing» | | | | |
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| The working program was approved at the meeting of the department | | | | |
| **Department of Nanoelectronics** | | | | |
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| Minutes of meeting from 02.03.2021 № 3  Head of the Department A. Sigov \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ | | | | |

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| **Approval of the WPD for execution in the next academic year** | | | | |
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| The working program was revised, discussed and approved for execution in the 2022-2023 academic year at a meeting of the department | | | | |
| **Department of Nanoelectronics** | | | | |
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|  | Minutes of meeting from \_\_ \_\_\_\_\_\_\_\_\_\_ 2022. № \_\_  Head of the Department \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ | | | |
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| **Approval of the WPD for execution in the next academic year** | | | | |
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| The working program was revised, discussed and approved for execution in the 2023-2024 academic year at a meeting of the department | | | | |
| **Department of Nanoelectronics** | | | | |
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|  | Minutes of meeting from \_\_ \_\_\_\_\_\_\_\_\_\_ 2023. № \_\_  Head of the Department \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ | | | |
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| **Approval of the WPD for execution in the next academic year** | | | | |
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| The working program was revised, discussed and approved for execution in the 2024-2025 academic year at a meeting of the department | | | | |
| **Department of Nanoelectronics** | | | | |
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|  | Minutes of meeting from \_\_ \_\_\_\_\_\_\_\_\_\_ 2024. № \_\_  Head of the Department \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ | | | |
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| **Approval of the WPD for execution in the next academic year** | | | | |
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| The working program was revised, discussed and approved for execution in the 2025-2026 academic year at a meeting of the department | | | | |
| **Department of Nanoelectronics** | | | | |
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|  | Minutes of meeting from \_\_ \_\_\_\_\_\_\_\_\_\_ 2025. № \_\_  Head of the Department \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ | | | |
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| **1. OBJECTIVES OF MASTERING THE DISCIPLINE (MODULE)** | | | | | |
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| The discipline «Сomputer-aided design systems» aims to contribute to the formation of students’ competencies, provided by this work program in accordance with the requirements of FSES HE in the direction of training 11.04.04 Electronics and nanoelectronics, taking into account the specifics of the profile – «Engineering of modern materials for information technology, renewable energy and sensing». | | | | | |
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| **2. PLACE OF DISCIPLINE (MODULE) IN THE STRUCTURE OF THE EDUCATIONAL PROGRAM** | | | | | |
|  | Direction of training: |  | 11.04.04 Electronics and nanoelectronics | | |
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|  | Profile: |  | Engineering of modern materials for information technology, renewable energy and sensing | | |
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|  | Block: |  | Disciplines (modules) | | |
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|  | Part: |  | Part of the curriculum formed by the participants of educational | | |
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|  | Total labor intensity: |  | 6 credits (216 academic hours). | | |
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| **3. THE STUDENT’S COMPETENCIES FORMED AS A RESULT OF MASTERING THE DISCIPLINE (MODULE)** | | | | | |
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| As a result of mastering the practice, the student must master the following competencies: | | | | | |
| **PC-3** - Capable of determining possible physical implementation options, physical and mathematical models of micro- and nanosystems and using software tools for their design and modeling | | | | | |
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| **PLANNED RESULTS OF TRAINING IN THE DISCIPLINE (MODULE), CHARACTERIZING THE FORMATION OF COMPETENCIES** | | | | | |
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| **PC-3 : Capable of determining possible physical implementation options, physical and mathematical models of micro- and nanosystems and using software tools for their design and modeling** | | | | | |
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| **PC-3.1: Defines possible variants of physical and mathematical models in the field of nanoelectronics** | | | | | |
| **To know:** | | | | | |
| - fundamentals of VLSI construction based on CMOS circuits and modern Computer-aided design systems and modeling of electronic component base devices | | | | | |
| **Be able to:** | | | | | |
| - apply in practice knowledge of the principles of building integrated circuit elements, physical and mathematical models of electronic component base elements and tools of computer-aided design and modeling systems for the development of electronic component base devices | | | | | |
| **Possess:** | | | | | |
| - methods of designing and modeling electronic component base devices based on modern specialized computer-aided design software packages | | | | | |
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| **PC-3.2: Uses software tools for designing and modeling electronics elements** | | | | | |

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| **To know:** | | | | | | |
| - methods and means of automation of technical experiments and design of electronic devices and systems | | | | | | |
| **Be able to:** | | | | | | |
| - apply in practice methods and means of automation of technical experiments and design of electronic devices and systems | | | | | | |
| **Possess:** | | | | | | |
| - tools and methods of automation of technical experiments and design of electronic devices and systems | | | | | | |
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| **AS A RESULT OF STUDYING THE DISCIPLINE (MODULE), THE STUDENT MUST** | | | | | | |
| **To know:** | | | | | | |
| - methods and means of automation of technical experiments and design of electronic devices and systems | | | | | | |
| - fundamentals of VLSI construction based on CMOS circuits and modern Computer-aided design systems and modeling of electronic component base devices | | | | | | |
| **Be able to:** | | | | | | |
| - apply in practice methods and means of automation of technical experiments and design of electronic devices and systems | | | | | | |
| - apply in practice knowledge of the principles of building integrated circuit elements, physical and mathematical models of electronic component base elements and tools of computer-aided design and modeling systems for the development of electronic component base devices | | | | | | |
| **Possess:** | | | | | | |
| - tools and methods of automation of technical experiments and design of electronic devices and systems | | | | | | |
| - methods of designing and modeling electronic component base devices based on modern specialized computer-aided design software packages | | | | | | |
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| **4. STRUCTURE AND CONTENT OF THE DISCIPLINE (MODULE)** | | | | | | |
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| During the training sessions, the organization ensures the development of students’ teamwork skills, interpersonal communication, decision-making and leadership qualities. | | | | | | |
| **Code** | **Name of sections and topics /type of classes/** | | **Semester** | **Academic Hours** | **Competencies** | |
| **1. Methods and tools for designing solid-state electronics devices and integrated circuits.** | | | | | | |
| **1.1** | **Lecture** **1.** **MOSFETs. Inverter (Lec).** MOSFETs. Inverter | | 2 | 2 | PC-3.1 | |

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| **1.2** | **Lecture** **2.** **Combinational logic circuits. (Lec).** Levels of implementation of combinational logic circuits and parameters to be optimized. Advantages and disadvantages of CMOS. Typical combinational schemes. Drivers. Example. Typical combinational schemes. Encoders. Example. Typical combinational schemes. Decoders. Example. Typical combinational schemes. Multiplexer-demultiplexer. Typical combinational schemes. A half-adder and a full adder of two half-sums. Typical combinational schemes. Combinational single-digit adder. Typical combinational schemes. Complementary pass-through logic circuits. Typical combinational schemes. Single-bit adder on complementary keys. Dynamic logic circuits. The principle of operation. Dynamic logic circuits. Their advantages. A domino-type scheme. Implementation of the "third" state (Z-state). Output with three states. Finite automata: sequential synchronous circuits. Triggers are like the simplest finite automata. Triggers on combination valves. Dynamic latches. Semiconductor memory. Classification of semiconductor memory. Static and dynamic memory. Characteristics of different types of memory. Memory architecture with an arbitrary selection. NAND and NOR ROMs. Programmable gate matrices. Repeatedly reprogrammable memory. Static operational memory. Elements of dynamic operational memory. The main parameters of memory circuits. | 2 | 2 | PC-3.1 |

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| **1.3** | **Lecture** **3.** **Sequential logic circuits** **(Lec).** Sequential synchronous circuits as finite automata. R-S triggers. Schemes on fans and truth tables. Synchronous R-S trigger. Time diagram. D-trigger. Time diagram. The simplest finite automata: circuits with two internal states, triggers. JK trigger. Truth tables. T and D triggers built on the basis of the JK trigger. Time parameters of triggers. Competitions in triggers. CMOS pseudostatic latch. The synchronization scheme of the D-trigger front. Synchronization by the JK trigger front. MS trigger. Basic schemes of triggers on combination valves. A clocked RS trigger on the CMOS. The principle of operation. Clocked CMOS digital circuits (TC MOSFET). Triggers that are insensitive to clock pulse overlap. The principle of operation. MS D-trigger schematics. MS D is a trigger with the initial state setting. The scheme of formation of undiscovered pulses. Two-phase dynamic trigger. The principle of operation. Dynamic latch on the pass-through elements. The principle of operation. Schemes of dynamic latches on the fans. The principle of operation. Transfer valves in dynamic circuits. Dynamic circuits with pre-charging (PE). Problems in cascading PE circuits. The logic of "Domino". A clocked NP adder on CMOS. The principle of operation. | 2 | 2 | PC-3.1 |
| **1.4** | **Lecture** **4.** **Introduction to Integrated Circuit Design Methodology (Lec).** General concepts about the content of CAD packages: CAD, CAE, CALS, SAM, EDA. The main stages of creating an IP. Definition of the term technical specification for the VLSI project. Goals and objectives of the design process. What is a completed project? The main technical characteristics of the IC of a modern microprocessor. Justification of the need for automation of IP design. Levels of abstraction in the design of IC. The Gaisky-Kahn diagram. History. Stages of IP creation. Design levels. VLSI design cycle. Possible strategies for organizing the VLSI design process. | 2 | 2 | PC-3.1 |

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| **1.5** | **Lecture** **5.** **VLSI topology design (Lec).** The main masks that are required for the manufacture of an inverter in a p-type silicon wafer. The main technological operations that are required for the manufacture of an inverter in a p-type silicon wafer. The main elements of the CMOS topology. The main geometric parameters of an integral MOSFET are an integral resistor. Calculation of electrical resistance. Integral capacitor. Calculation of electrical capacity. Characteristic parameters of the IC technology. User-defined topology areas. Principles of the layout of objects on a chip. An algorithm for automated block placement. Assignment of I/O cells. Catering on a chip. Stages of topology synthesis. Valve circuit list. Stages of placing objects on a crystal. Placement strategies. Encounter Digital Implementation System of Cadence company is the main Cadence tools for computer-aided design of IC. Their purpose. DRC rules. Design standards and rules of the Ministry of Foreign Affairs-Conway. Typical topology errors. Terminology for the designation of topology elements. Masks for submicron topologies. Stages of topology verification. Antenna effect and its elimination. The cost of manufacturing modern VLSI and its components. The structure of the production costs of microcircuits of different generations Problems of size reduction: lithography and masks Modern methods of lithography and their applications. | 2 | 2 | PC-3.1, PC-3.2 |
| **1.6** | **Lecture** **6.** **Features of design and modeling of microwave devices (Lec).** Microwave ranges of electromagnetic radiation. Basic information from the theory of microwave devices. The method of complex amplitudes. Maxwell 's equations . Long lines. Telegraphic equations and transmission line parameters. Standing waves. Consistent load. No-load and short-circuit load. Mismatched load. Reflection coefficient. The Wolpert-Smith diagram. Justification of the construction of the Wolpert-Smith diagram. Examples of the application of the Wolpert-Smith diagram. S-parameters. | 2 | 2 | PC-3.1, PC-3.2 |

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| **1.7** | **Lecture** **7.** **Overview of modern systems used for the design and modeling of electronic component base** **(Lec).** Introduction: the Europractice Consortium. CAD for modeling new materials and devices: COMSOL Multiphysics, ANSYS, TCAD Sentaurus, Silvaco, CoventorWare. CAD for the design of integrated circuits, systems on a chip and systems in a housing: XILINX, INTEL (Altera), Cadence Design Systems, Synopsys, Siemens (Mentor Graphics). CAD for the design of printed circuit boards. General information about microwave devices, methods of analysis and calculation of their parameters. CAD for the design and modeling of microwave devices. Modeling and design of electronic devices and systems based on ECB. | 2 | 2 | PC-3.1, PC-3.2 |
| **1.8** | **Lecture** **8.** **Scaling problems in VLSI design (Lec).** The main parameters of the MOSFET that affect its characteristics. The main manufacturers of semiconductor ICS in the country. The main provisions of the Strategy for the development of the electronic industry of Russia until 2030. Calculation of the yield of suitable. Characteristic parameters of the IC technology. Technological operations that are additionally applied when reducing the size of transistors. Limitations of further miniaturization of transistors by the basic CMOS technology. The main problems of microminiaturization of MOSFETs. Formation of a smooth p-n transition in a 0.18 microns n-channel MOSFET. Ways to increase the performance of the transistor. What parameters affect the threshold voltage, and how? Problems with reducing the size of interconnects. Promising CMOS VLSI technologies. | 2 | 2 | PC-3.1, PC-3.2 |
| **1.9** | **Tests Execution (Pr).** PR 1. MOSFET transistors. CMOS inverter. | 2 | 2 | PC-3.1, PC-3.2 |
| **1.10** | **Tests Execution (Pr).** PR 2. Combinational logic circuits. | 2 | 2 | PC-3.1, PC-3.2 |
| **1.11** | **Tests Execution (Pr).** PR 3. Sequential logic circuits. | 2 | 2 | PC-3.1, PC-3.2 |
| **1.12** | **Tests Execution (Pr).** PR 4. Introduction to integrated circuit design methodology. | 2 | 2 | PC-3.1, PC-3.2 |
| **1.13** | **Tests Execution (Pr).** PR 5. VLSI topology design. | 2 | 2 | PC-3.1, PC-3.2 |
| **1.14** | **Tests Execution (Pr).** PR 6. Modeling of electronic circuits. | 2 | 2 | PC-3.1, PC-3.2 |
| **1.15** | **Solution of the control work (Pr).** PR 7. Verification work | 2 | 2 | PC-3.1, PC-3.2 |

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| **1.16** | **Tests Execution (Pr).** PR 8. Scaling problems in VLSI design. | 2 | 2 | PC-3.1 |
| **1.17** | **Performing practical tasks (Pr).** PR 9. Application of the method of complex amplitudes for the calculation of circuits. | 2 | 2 | PC-3.1 |
| **1.18** | **Performing practical tasks (Pr).** PR 10. Long lines and methods for determining their parameters. | 2 | 2 | PC-3.1 |
| **1.19** | **Performing practical tasks (Pr).** PR 11. Volpert-Smith diagrams. | 2 | 2 | PC-3.1 |
| **1.20** | **Performing practical tasks (Pr).** PR 12. Systems of parameters of two- and four-pole S-parameters of microwave devices and methods of their determination. | 2 | 2 | PC-3.1 |
| **1.21** | **Performing practical tasks (Pr).** PR 13. CAD tools for modeling microwave devices. Calculation of circuits with passive components. | 2 | 2 | PC-3.1 |
| **1.22** | **Performing practical tasks (Pr).** PR 14. Modeling of microwave devices. Modeling of filter schemes. | 2 | 2 | PC-3.1 |
| **1.23** | **Performing practical tasks (Pr).** PR 15. Modeling and calculation of microwave circuits according to the libraries of manufacturers of electronic component base. | 2 | 2 | PC-3.1 |
| **1.24** | **Performing practical tasks (Pr).** PR 16. Modeling of frequency dependencies of filter parameters as a four-pole. | 2 | 2 | PC-3.1 |
| **1.25** | **Performing practical tasks (Pr).** PR 17. Modeling of frequency dependencies of filter parameters as a four-pole. | 2 | 2 | PC-3.1 |
| **1.26** | **Performing practical tasks (Pr).** PR 18. Adjustment and optimization of parameters using the ADS system. | 2 | 2 | PC-3.1 |
| **1.27** | **Performing practical tasks (Pr).** PR 19. Adjustment and optimization of parameters using the ADS system. | 2 | 2 | PC-3.1 |
| **1.28** | **Performing practical tasks (Pr).** PR 20. Modeling and calculation of microwave amplifier circuits. | 2 | 2 | PC-3.1 |
| **1.29** | **Performing practical tasks (Pr).** PR 21. Modeling and calculation of microwave amplifier circuits. | 2 | 2 | PC-3.1 |
| **1.30** | **Performing practical tasks (Pr).** PR 22. Implementation of design procedures of a typical topology design route based on the use of Cadence Design Systems CAD tools and on the example of a microprocessor with MIPS architecture (Microprocessor without Interlocked Pipeline Stages). The design route. | 2 | 2 | PC-3.1 |
| **1.31** | **Performing practical tasks (Pr).** PR 23. MIPS microprocessor. Microarchitecture analysis. | 2 | 2 | PC-3.1 |

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| **1.32** | **Performing practical tasks (Pr).** PR 24. MIPS microprocessor. Microarchitecture analysis. | 2 | 2 | PC-3.1 |
| **1.33** | **Performing practical tasks (Pr).** PR 25. The MIPS microprocessor. Behavioral description. | 2 | 2 | PC-3.1 |
| **1.34** | **Performing practical tasks (Pr).** PR 26. MIPS microprocessor. Behavioral description. | 2 | 2 | PC-3.1 |
| **1.35** | **Performing practical tasks (Pr).** PR 27. MIPS microprocessor. Topology design. | 2 | 2 | PC-3.1 |
| **1.36** | **Performing practical tasks (Pr).** PR 28. MIPS microprocessor. Topology design. | 2 | 2 | PC-3.1 |
| **1.37** | **Performing practical tasks (Pr).** PR 29. Tools for checking integrated circuit designs. | 2 | 2 | PC-3.1 |
| **1.38** | **Performing practical tasks (Pr).** PR 30. Tools for checking integrated circuit designs. | 2 | 2 | PC-3.1 |
| **1.39** | **Performing practical tasks (Pr).** PR 31. Modeling of microwave devices by harmonic balance method. | 2 | 2 | PC-3.1 |
| **1.40** | **Performing practical tasks (Pr).** PR 32. Modeling of microwave devices by harmonic balance method. | 2 | 2 | PC-3.1 |
| **1.41** | **Completing coursework** **(project)** **(IWS).** Methods and tools for designing solid-state electronics devices and integrated circuits. | 2 | 50 | PC-3.1, PC-3.2 |
| **1.42** | **Homework (IWS).** IWS 25. Answers to self-test questions. MOSFETs. The inverter. | 2 | 2 | PC-3.1 |
| **1.43** | **Homework (IWS).** IWS 26. Answers to self-test questions. Combinational logic circuits | 2 | 2 | PC-3.1 |
| **1.44** | **Homework (IWS).** IWS 27. Answers to self-test questions. Sequential logic circuits | 2 | 2 | PC-3.1 |
| **1.45** | **Homework (IWS).** IWS 28. Answers to self-test questions. Introduction to Integrated Circuit Design Methodology | 2 | 2 | PC-3.1 |
| **1.46** | **Homework (IWS).** IWS 29. Answers to self-test questions. VLSI topology design | 2 | 2 | PC-3.1 |
| **1.47** | **Homework (IWS).** IWS 30. Answers to self-test questions. Modeling of electronic circuits | 2 | 2 | PC-3.1 |
| **1.48** | **Homework (IWS).** IWS 31. Overview of modern systems used for the design and modeling of electronic component base. | 2 | 2 | PC-3.1 |

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| **1.49** | **Homework (IWS).** IWS 32. Scaling problems in VLSI design | | | 2 | 2 | PC-3.1 | |
| **1.50** | **Preparation for classroom classes (IWS).** Preparation for lectures, practical and laboratory classes | | | 2 | 16 | PC-3.1 | |
| **2. Intermediate certification (Coursework)** | | | | | | | |
| **2.1** | **Preparation for the intermediate certification (КР).** | | | 2 | 16 | PC-3.1, PC-3.2 | |
| **2.2** | **Contact work with the teacher during the intermediate certification (CWC).** | | | 2 | 2 | PC-3.1, PC-3.2 | |
| **3. Intermediate certification (exam)** | | | | | | | |
| **3.1** | **Preparation for the intermediate certification (Exam).** | | | 2 | 33,65 | PC-3.1, PC-3.2 | |
| **3.2** | **Contact work with the teacher during the intermediate certification (CWC).** | | | 2 | 2,35 | PC-3.1, PC-3.2 | |
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| **5. EVALUATION MATERIALS** | | | | | | | |
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| **5.1. List of competencies** | | | | | | | |
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| List of competencies, the development of which the study of the discipline is aimed at «Сomputer-aided design systems», with an indication of the results of their formation in the process of mastering the educational program, presented in paragraph 3 of this work program | | | | | | | |
| **5.2. Typical control questions and tasks** | | | | | | | |
| 1. Valve circuit list (netlist).  2. The main stages of the RTL Compiler.  3. Setting paths to library files and HDL descriptions.  4. Uploading project library files to the database.  5. Translation (assembly) of the project.  6. Setting user restrictions.  7. Project synthesis.  8. Analysis of the results.  9. Uploading project files.  10. How to work with RTL Compiler.  11. Basic commands of the script description.  12. The main tools of the Encounter program.  13. Preparing to work with Encounter.  14. Creating a new project. | | | | | | | |
| **5.3. Fund of evaluation Materials** | | | | | | | |
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| A complete list of evaluation materials is provided in the Appendix 1. | | | | | | | |
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| **6. MATERIAL, TECHNICAL, EDUCATIONAL AND METHODOLOGICAL SUPPORT OF THE DISCIPLINE (MODULE)** | | | | | | | |
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| **6.1. MATERIAL AND TECHNICAL SUPPORT OF THE DISCIPLINE (МОДУЛЯ)** | | | | | | | |
| **Name of premises** | | | **List of main equipment** | | | | |
| Classroom for lectures and seminars, group and individual consultations, ongoing monitoring and intermediate certification | | | Multimedia equipment, specialized furniture, sets of demonstration equipment and educational and visual aids that provide thematic illustrations. | | | | |

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| Educational laboratory | | | | Computer equipment with the ability to connect to the Internet, ATLYS c FPGA Spartan 6 demo boards, NI ELVIS laboratory stands, converter, digital oscilloscope, RLC meter, demo boards with MEMS accelerometer, power supply | |
| A room for independent work of students | | | | Computer equipment with the ability to connect to the Internet and provide access to the electronic information and educational environment of the organization. | |
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| **6.2. LIST OF SOFTWARE** | | | | | |
| 1. |  | Microsoft Windows. Contract No. 32009183466 from 02.07.2021. | | | |
| 2. |  | Microsoft Office. Contract No. 32009183466 from 02.07.2021. | | | |
| 3. |  | COMSOL Multiphysics. Sublicense contract No. 31705027784 from 12.05.2017. | | | |
| 4. |  | LabVIEW. Contract No. 0373100029519000161 from 10.12.2019 г. | | | |
| 5. |  | Atmel Studio. Free software | | | |
| 6. |  | Vivado Design Suite WebPACK. Free software | | | |
| 7. |  | Xilinx ISE Web Pack. Free software | | | |
| 8. |  | National Instrument complete with NI ELVIS. Licensed software with serial number M84X87575 | | | |
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| **6.3. RECOMMENDED LITERATURE** | | | | | |
| **6.3.1. Basic literature** | | | | | |
| 1. |  | Pevtsov E. Ph., Demenkova T. A., Al'-Natah R. I. Osnovy modelirovaniya i proektirovaniya MEMS v SAPR CoventorWare [Electronic resource]:uchebnoe posobie. - M.: MIREA, 2016. - – Access mode: http://library.mirea.ru/secret/ab/1242.iso | | | |
| 2. |  | Pevtsov E. Ph., Tarasov I. E., Minnebaev V. M. Avtomatizirovannoe proektirovanie cifrovyh skhem [Electronic resource]:uchebnoe posobie. - M.: MIREA, 2016. - – Access mode: http://library.mirea.ru/secret/ab/1243.iso | | | |
| 3. |  | Indrishenok V. I., Pevtsov E. Ph. Osnovy priborno-tekhnologicheskogo modelirovaniya v Sentaurus TCAD [Electronic resource]:uchebnoe posobie. - M.: MIREA, 2018. - – Access mode: http://library.mirea.ru/secret/25052018/1738.iso | | | |
| 4. |  | Pevtsov E. Ph., Krutov V. V. Osnovy avtomatizirovannogo proektirovaniya SVCH ustrojstv i sistem [Electronic resource]:uchebnoe posobie. - M.: RTU MIREA, 2018. - – Access mode: http://library.mirea.ru/secret/06032019/1975.iso | | | |
| 5. |  | Harris D. M., Harris S. L. Cifrovaya skhemotekhnika i arhitektura komp'yutera:per. s angl.. - M.: DMK Press, 2018. - 792 s. | | | |
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| **6.3.2. Additional literature** | | | | | |
| 1. |  | Krekraft D. I., Dzherdzhli S. Analogovaya elektronika. Skhemy, sistemy, obrabotka signala:[Ucheb. posobie]. - M.: Tekhnosfera, 2005. - 360 s. | | | |
| 2. |  | Shchuka A. A., A. Sigov Elektronika:Ucheb. posobie dlya vuzov. - SPb.: BHV-Peterburg, 2005. - 799 s. | | | |
| 3. |  | Horovic P., Hill U. Iskusstvo skhemotekhniki:Per. s angl.. - M.: Mir, 2003. - 704 s. | | | |
| 4. |  | Rabai Zh. M., CHandrakasan A., Nikolich B. Cifrovye integral'nye skhemy:Metologiya proektirovaniya. - M.: Vil'yams, 2007. - 911 s. | | | |
| 5. |  | Tarasov I. E., Pevtsov E. Ph. Osnovy proektirovaniya cifrovyh ustrojstv s ispol'zovaniem yazyka VERILOG [Electronic resource]:uchebnoe posobie. - M.: MGTU MIREA, 2011. - – Access mode: http://library.mirea.ru/secret/e\_816.iso | | | |
| 6. |  | Titce U. Poluprovodnikovaya skhemotekhnika:. - , 2008. - 827 s. | | | |
| 7. |  | Hartov V. YA. Mikrokontrollery AVR. Praktikum dlya nachinayushchih:uchebnoe posobie dlya vuzov. - M.: Izd-vo MGU im. Baumana, 2012. - 280 s. | | | |

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| 8. |  | Bessonov A. S. Tekhnologii programmirovaniya posledovatel'nyh interfejsov semejstva RS-232 v izmeritel'nyh sistemah:Ucheb. posobie. - M.: MIREA, 2011. - 143 s. | | |
| 9. |  | Ugryumov E. P. Cifrovaya skhemotekhnika:Ucheb. posobie dlya vuzov i tekhnikumov. - SPb.: BHV-Peterburg, 2001. - 518 s. | | |
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| **6.4. RECOMMENDED LIST OF MODERN PROFESSIONAL DATABASES AND INFORMATION REFERENCE SYSTEMS** | | | | |
| 1. |  | Website of the PTI Department of Nanoelectronics https://fks.mirea.ru | | |
| 2. |  | Database Web of Science  http://www.webofknowledge.com | | |
| 3. |  | News and analytical portal "Vremya elektroniki "  http://www.russianelectronics.ru | | |
| 4. |  | Journal «Nano- and Microsystem Technology»  http://www.microsystems.ru | | |
| 5. |  | Imec R&D, nano electronics and digital technologies  https://www.imec.be | | |
| 6. |  | iXBT — online publication about computer technology  https://www.ixbt.com | | |
| 7. |  | An international resource for the search and exchange of scientific publications  https://www.researchgate.net | | |
| 8. |  | Information and reference portal of scientific publications of domestic and foreign authors «Google Academy»  https://www.scholar.google.ru | | |
| 9. |  | Russian Technological Journal  https://www.rtj.mirea.ru | | |
| 10. |  | Ministry of Science and Higher Education of the Russian Federation  https://www.minobrnauki.gov.ru | | |
| 11. |  | Natural Science educational Portal http://www.en.edu.ru | | |
| 12. |  | Scientific Electronic Library http://www.elibrary.ru | | |
| 13. |  | COMSOL Multiphysics® Software for multiphysical modeling https://www.COMSOL.ru | | |
| 14. |  | Information portal of the Russian Science Foundation http://www.rscf.ru | | |
| 15. |  | Russian Foundation for Basic Research https://www.rfbr.ru | | |
| 16. |  | Information portal «Popular nanotechnologies» http://www.popnano.ru | | |
| 17. |  | Electronic fund of legal and regulatory technical documentation Tekhnoexpert http://www.docs.cntd.ru | | |
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| **6.5. METHODICAL INSTRUCTIONS FOR STUDENTS STUDYING THE DISCIPLINE (MODULE)** | | | | |
| The student’s independent work is aimed at preparing for academic classes and at developing knowledge, skills and abilities provided for in the discipline program.  In accordance with the curriculum, the discipline may include Lectures, practical classes and Laboratory work, as well as the execution and defense of a course project (work). Successful study of the discipline requires attending all types of classes, completing teacher assignments and familiarization with basic and additional literature. Depending on the activities provided for in the curriculum and section 4 of this program, the student chooses methodological guidelines for independent work from the ones listed below.  When preparing for lecture classes, students need to:  review the summary of the material of the previous lecture before the next lecture. If there are difficulties in perceiving the material, you should refer to the main literary sources. | | | | |

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| If it was not possible to understand the material again, then contact the lecturer (according to the schedule of his consultations) or the teacher in practical classes.  Practical classes complete the study of the most important topics of the discipline. They serve to consolidate the studied material, develop the skills and abilities of preparing reports, messages, gaining experience in oral public speeches, conducting discussions, argumentation and defending the propositions put forward, as well as to monitor the degree of readiness of students in the discipline being studied by the teacher.  When preparing for a practical lesson, students have the opportunity to use the advice of a teacher.  When preparing for practical classes, students need to:  bring with you the literature recommended by the teacher for a specific lesson;  before the next practical lesson on the recommended literary sources, work out the theoretical material corresponding to the topic of the lesson;  at the beginning of classes, ask the teacher questions about the material that caused difficulties in understanding and mastering it when solving tasks set for independent solution;  during the seminar, give specific, clear answers to the substance of the questions;  at the training session, bring each task to the final solution, demonstrate an understanding of the calculations (analyses, situations), in case of difficulties, contact the teacher.  Students who have missed classes (regardless of the reasons), who do not have a written solution to problems or are not prepared for this practical lesson, are recommended to come to the teacher’s consultation no later than 2 weeks and report on the topic studied in the lesson.  The methodological guidelines necessary for studying and passing the discipline are given as part of the educational program. | | |
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| **6.6. METHODOLOGICAL RECOMMENDATIONS FOR THE TRAINING OF PERSONS WITH LIMITED HEALTH OPPORTUNITIES AND THE DISABLED** | | |
| The development of the discipline by students with disabilities can be organized both jointly with other students and in separate groups. Special conditions are assumed for students with disabilities to receive education.  The teaching staff gets acquainted with the psychological and physiological characteristics of students with disabilities and persons with disabilities, individual rehabilitation programs for the disabled (if available). If necessary, additional teaching support is provided by tutors, psychologists, social workers, trained assistants.  In accordance with the methodological recommendations of the Ministry of Education and Science of the Russian Federation (approved April 8, 2014 N AK-44/05vn), the course is supposed to use socially active and reflective teaching methods, technologies of socio-cultural rehabilitation in order to assist in establishing full-fledged interpersonal relationships with other students, creating a comfortable psychological climate in the student group. Selection and development of educational materials are made taking into account the provision of material in various forms: auditory, visual, using special technical means and information systems.  Mediamaterials should also be used and adapted taking into account the individual characteristics of the training of persons with disabilities.  The development of the discipline by persons with disabilities is carried out using general and special purpose teaching tools (personal and collective use). Material and technical support provides for the adaptation of classrooms to the needs of persons with disabilities.  The form of certification for students with disabilities is established taking into account individual psychophysical characteristics. For students with HIA, an accessible form of assignment of assessment tools is provided, namely: | | |

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| - in printed or electronic form (for persons with disorders of the musculoskeletal system);  - in printed or electronic form with enlarged font and contrast (for persons with hearing, speech, vision impairments);  - reading the task aloud by the assistant (for visually impaired persons).  Students with disabilities have increased time to prepare answers to control questions. For such students, an accessible form of providing answers to tasks is provided, namely:  - written on paper or a set of answers on a computer (for persons with hearing and speech impairments);  - choosing an answer from possible options using the services of an assistant (for people with musculoskeletal disorders);  - oral interview (for persons with visual impairments, musculoskeletal system).  If necessary, for students with disabilities, the procedure for evaluating learning outcomes can be carried out in several stages. |

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| Federal State Budget Educational Institution of Higher Education  «MIREA – Russian Technological University» | | | | | | | | | | | | | | | | | | | | | |
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| Working program of the discipline (module) | | | | | | | | | | | | | | | | | | | | | |
| **Sociology** | | | | | | | | | | | | | | | | | | | | | |
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|  | Department leading the training | | | | | |  |  | **Department of Humanities and Social Sciences** | | | | | | | | | | | | |
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|  | Direction of training | | | | | | |  | **11.04.04 Electronics and nanoelectronics** | | | | | | | | | | | | |
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|  | Profile | | | | | | |  | **Engineering of modern materials for information technology, renewable energy and sensing** | | | | | | | | | | | | |
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|  | Qualification | | | | |  |  |  | **Master** | | | | | | | | | | | | |
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|  | Form of education | | | | |  |  |  | **Full-time** | | | | | | | | | |  |  |  |
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| **Distribution of discipline hours and forms of intermediate certification by semesters** | | | | | | | | | | | | | | | | | | | | | |
| Semester | | Credits | Distribution of hours | | | | | | | | | | | | | | | Forms of intermediate attestation | | |  |
| Total | Lectures | | | | Laboratory work | | | Practical classes | Independent work of students | | Contact work during practice and (or) certification | | | Control of training |  |
| 1 | | 2 | 72 | 16 | | | | 0 | | | 0 | 38 | | 0,25 | | | 17,75 | Test | | |  |
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| The program was made by: |  |  |  |  |
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| *Ph.D. Philosophical Sciences, Associate Professor, E. Arapova \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_* | | | | |
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| Working program of the discipline | | |  |  |
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| it is developed in accordance with FSES HE: | | |  |  |
| Federal State Educational Standard of Higher Education - Magistracy in the Direction of training 11.04.04 Electronics and nanoelectronics (order of the Ministry of Science and Higher Education of the Russian Federation from 22.09.2017. № 959) | | | | |
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| it is based on the curriculum: | | |  |  |
| Direction of training: 11.04.04 Electronics and nanoelectronics  Profile: «Engineering of modern materials for information technology, renewable energy and sensing» | | | | |
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| The working program was approved at the meeting of the department | | | | |
| **Department of Humanities and Social Sciences** | | | | |
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| Minutes of meeting from 28.08.2020 № 1  Head of the Department I. Gajdamashko \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ | | | | |

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| **Approval of the WPD for execution in the next academic year** | | | | |
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| The working program was revised, discussed and approved for execution in the 2021-2022 academic year at a meeting of the department | | | | |
| **Department of Humanities and Social Sciences** | | | | |
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|  | Minutes of meeting from \_\_ \_\_\_\_\_\_\_\_\_\_ 2021. № \_\_  Head of the Department \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ | | | |
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| **Approval of the WPD for execution in the next academic year** | | | | |
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| The working program was revised, discussed and approved for execution in the 2022-2023 academic year at a meeting of the department | | | | |
| **Department of Humanities and Social Sciences** | | | | |
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|  | Minutes of meeting from \_\_ \_\_\_\_\_\_\_\_\_\_ 2022. № \_\_  Head of the Department \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ | | | |
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| **Approval of the WPD for execution in the next academic year** | | | | |
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| The working program was revised, discussed and approved for execution in the 2023-2024 academic year at a meeting of the department | | | | |
| **Department of Humanities and Social Sciences** | | | | |
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|  | Minutes of meeting from \_\_ \_\_\_\_\_\_\_\_\_\_ 2023. № \_\_  Head of the Department \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ | | | |
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| **Approval of the WPD for execution in the next academic year** | | | | |
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| The working program was revised, discussed and approved for execution in the 2024-2025 academic year at a meeting of the department | | | | |
| **Department of Humanities and Social Sciences** | | | | |
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|  | Minutes of meeting from \_\_ \_\_\_\_\_\_\_\_\_\_ 2024. № \_\_  Head of the Department \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ | | | |
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| **1. OBJECTIVES OF MASTERING THE DISCIPLINE (MODULE)** | | | | | |
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| The discipline «Sociology» aims to contribute to the formation of students’ competencies, provided by this work program in accordance with the requirements of FSES HE in the direction of training 11.04.04 Electronics and nanoelectronics, taking into account the specifics of the profile – «Engineering of modern materials for information technology, renewable energy and sensing». | | | | | |
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| **2. PLACE OF DISCIPLINE (MODULE) IN THE STRUCTURE OF THE EDUCATIONAL PROGRAM** | | | | | |
|  | Direction of training: |  | 11.04.04 Electronics and nanoelectronics | | |
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|  | Profile: |  | Engineering of modern materials for information technology, renewable energy and sensing | | |
|  |  |  |
|  | Block: |  | Disciplines (modules) | | |
|  |  |  |
|  | Part: |  | Mandatory part | | |
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|  | Total labor intensity: |  | 2 credits (72 academic hours). | | |
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| **3. THE STUDENT’S COMPETENCIES FORMED AS A RESULT OF MASTERING THE DISCIPLINE (MODULE)** | | | | | |
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| As a result of mastering the practice, the student must master the following competencies: | | | | | |
| **UC-3** - Capable to organize and lead the work of the team, developing team strategy to achieve this goal | | | | | |
| **UC-5** - Capable to analyze and take into account the diversity of cultures in the process of intercultural interaction | | | | | |
| **UC-6** - Capable to determine and implement the priorities of his own activities and ways to improve it based on self-assessment | | | | | |
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| **PLANNED RESULTS OF TRAINING IN THE DISCIPLINE (MODULE), CHARACTERIZING THE FORMATION OF COMPETENCIES** | | | | | |
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| **UC-3 : Capable to organize and lead the work of the team, developing team strategy to achieve this goal** | | | | | |
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| **UC-3.1: Develops strategy of teamwork and on its basis organizes the selection of team members to achieve the goal** | | | | | |
| **To know:** | | | | | |
| - principles and technologies of developing a teamwork strategy to achieve the goal, processes of internal team dynamics, technologies and methods of cooperation in teamwork; methods of selecting team members. | | | | | |
| **Be able to:** | | | | | |
| - apply the theoretical foundations of developing a teamwork strategy, select team members to achieve the goal in practice | | | | | |
| **Possess:** | | | | | |
| - the skills of selecting team members and organizing teamwork in order to achieve the set goal. | | | | | |
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| **UC-3.2: Organizes and modifies the work of the team, including on the basis of collegial decisions** | | | | | |
| **To know:** | | | | | |
| - the basics of organizing and adjusting the work of the team taking into account collegial decisions; main characteristics of the collective; features of a multicultural collective | | | | | |

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| **Be able to:** | | |
| - Organize and manage the work of the team, manage the processes of group dynamics; analyze the state of the social group, | | |
| **Possess:** | | |
| - skills of developing leadership qualities and using them in team management, identifying and assessing conflict situations and choosing the optimal way out of them | | |
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| **UC-5 : Capable to analyze and take into account the diversity of cultures in the process of intercultural interaction** | | |
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| **UC-5.1: Analyzes the most important ideological and cultural values** | | |
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| **To know:** | | |
| - various historical types of cultures | | |
| **Be able to:** | | |
| - explain the phenomenon of culture, its role in human life; adequately assess intercultural dialogues in modern society | | |
| **Possess:** | | |
| - skills of forming a psychologically safe environment in professional activity | | |
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| **UC-5.2: Builds social and professional interaction taking into account the peculiarities of business and general culture of representatives of other ethnic groups and confessions, various social groups** | | |
| **To know:** | | |
| - mechanisms of intercultural interaction in society at the present stage, principles of correlation of global and national cultural processes | | |
| **Be able to:** | | |
| - tolerant interaction with representatives of different cultures | | |
| **Possess:** | | |
| - skills of intercultural interaction taking into account the diversity of cultures | | |
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| **UC-6 : Capable to determine and implement the priorities of his own activities and ways to improve it based on self-assessment** | | |
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| **UC-6.1: Assesses his resources and their limits (personal, situational, temporary) for the successful completion of the assigned task** | | |
| **To know:** | | |
| - problems and specifics of various types of resources, basic concepts of sociological knowledge. | | |
| **Be able to:** | | |
| - apply the theoretical foundations of assessing the resources of the individual, develop strategies for the effective performance of the assigned task | | |
| **Possess:** | | |
| - assessment and management skills of personal, situational, time resources, the ability to improve on the basis of self-assessment | | |
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| **UC-6.2: Defines educational needs and ways to improve one’s own (including professional) activities based on self-assessment** | | |
| **To know:** | | |
| - definition and role of self-esteem in the development of personality, the essence, characteristics and specifics of educational needs | | |
| **Be able to:** | | |
| - use ways to improve activities in various types of activities, engage in introspection. | | |

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| **Possess:** | | | | | | |
| - methods of determining and managing educational needs, skills to improve their activities and self-development based on self-assessment | | | | | | |
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| **AS A RESULT OF STUDYING THE DISCIPLINE (MODULE), THE STUDENT MUST** | | | | | | |
| **To know:** | | | | | | |
| - definition and role of self-esteem in the development of personality, the essence, characteristics and specifics of educational needs | | | | | | |
| - various historical types of cultures | | | | | | |
| - problems and specifics of various types of resources, basic concepts of sociological knowledge. | | | | | | |
| - mechanisms of intercultural interaction in society at the present stage, principles of correlation of global and national cultural processes | | | | | | |
| - the basics of organizing and adjusting the work of the team taking into account collegial decisions; main characteristics of the collective; features of a multicultural collective | | | | | | |
| - principles and technologies of developing a teamwork strategy to achieve the goal, processes of internal team dynamics, technologies and methods of cooperation in teamwork; methods of selecting team members. | | | | | | |
| **Be able to:** | | | | | | |
| - apply the theoretical foundations of developing a teamwork strategy, select team members to achieve the goal in practice | | | | | | |
| - tolerant interaction with representatives of different cultures | | | | | | |
| - apply the theoretical foundations of assessing the resources of the individual, develop strategies for the effective performance of the assigned task | | | | | | |
| - Organize and manage the work of the team, manage the processes of group dynamics; analyze the state of the social group, | | | | | | |
| - use ways to improve activities in various types of activities, engage in introspection. | | | | | | |
| - explain the phenomenon of culture, its role in human life; adequately assess intercultural dialogues in modern society | | | | | | |
| **Possess:** | | | | | | |
| - methods of determining and managing educational needs, skills to improve their activities and self-development based on self-assessment | | | | | | |
| - assessment and management skills of personal, situational, time resources, the ability to improve on the basis of self-assessment | | | | | | |
| - skills of developing leadership qualities and using them in team management, identifying and assessing conflict situations and choosing the optimal way out of them | | | | | | |
| - the skills of selecting team members and organizing teamwork in order to achieve the set goal. | | | | | | |
| - skills of intercultural interaction taking into account the diversity of cultures | | | | | | |
| - skills of forming a psychologically safe environment in professional activity | | | | | | |
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| **4. STRUCTURE AND CONTENT OF THE DISCIPLINE (MODULE)** | | | | | | |
| During the training sessions, the organization ensures the development of students’ teamwork skills, interpersonal communication, decision-making and leadership qualities. | | | | | | |
| **Code** | **Name of sections and topics /type of classes/** | | **Semester** | **Academic Hours** | **Competencies** | |
| **1. Sociology as a science. History of sociology** | | | | | | |

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| **1.1** | **Sociology as a science. History of sociology (Lec).** The subject of sociology. Structure and levels of sociological knowledge. The emergence and main stages of the development of sociology. O.Comte, G.Spencer, E.Durkheim, P.A. Sorokin, M.Weber, etc. | 1 | 2 | UC-5.1, UC- 5.2, UC-3.1, UC-3.2, UC- 6.1, UC-6.2 |
| **1.2** | **Preparation for classroom classes (IWS).** Preparation for lectures and practical classes | 1 | 5 | UC-5.1, UC- 5.2, UC-3.1, UC-3.2, UC- 6.1, UC-6.2 |
| **1.3** | **Performing practical tasks (Pr).** The subject of sociology. Structure and levels of sociological knowledge. The history of the development of sociological though. | 1 | 2 | UC-5.1, UC- 5.2, UC-3.1, UC-3.2, UC- 6.1, UC-6.2 |
| **2. Society as a social system. Social structure of society.** | | | | |
| **2.1** | **Society as a social system. Social structure of society.**  **(Lec).** Society as a social system: signs and typologies. Social inequality and the social structure of society. Social stratification. The concept of a social institution. | 1 | 2 | UC-5.1, UC- 5.2, UC-3.1, UC-3.2, UC- 6.1, UC-6.2 |
| **2.2** | **Performing practical tasks (Pr).** Society as a social system. Social institutions. Social progress and regression the social structure of society. Social inequality. Social stratification. | 1 | 2 | UC-5.1, UC- 5.2, UC-3.1, UC-3.2, UC- 6.1, UC-6.2 |
| **2.3** | **Preparation for classroom classes (IWS).** Preparation for lectures and practical classes | 1 | 2 | UC-5.1, UC- 5.2, UC-3.1, UC-3.2, UC- 6.1, UC-6.2 |
| **3. Social mobility. Sociology of personality** | | | | |
| **3.1** | **Social mobility. Sociology of personality (Lec).** Social mobility. Vertical and horizontal mobility. Intergenerational mobility. Patterns of vertical mobility. Sociology of personality. Sociological theories of personality. Social statuses and roles. | 1 | 2 | UC-5.1, UC- 5.2, UC-3.1, UC-3.2, UC- 6.1, UC-6.2 |
| **3.2** | **Performing practical tasks (Pr).** Social mobility. Personality as an object of research. Social behavior, social roles and social statuses. Socialization of personality. | 1 | 2 | UC-5.1, UC- 5.2, UC-3.1, UC-3.2, UC- 6.1, UC-6.2 |
| **3.3** | **Preparation for classroom classes (IWS).** Preparation for lectures and practical classes | 1 | 2 | UC-5.1, UC- 5.2, UC-3.1, UC-3.2, UC- 6.1, UC-6.2 |

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| **4. Sociology of conflict.**  **Sociological research** | | | | |
| **4.1** | **Sociology of conflict**  **Sociological research**  **(Lec).** Social conflicts: concept, causes, typology and dynamics. Sociological research as a tool for cognition of social reality | 1 | 2 | UC-5.1, UC- 5.2, UC-3.1, UC-3.2, UC- 6.1, UC-6.2 |
| **4.2** | **Performing practical tasks (Pr).** Sociology of conflict. The program of sociological research. Methods of concrete sociological research. | 1 | 2 | UC-5.1, UC- 5.2, UC-3.1, UC-3.2, UC- 6.1, UC-6.2 |
| **4.3** | **Preparation for classroom classes (IWS).** Preparation for lectures and practical classes | 1 | 2 | UC-5.1, UC- 5.2, UC-3.1, UC-3.2, UC- 6.1, UC-6.2 |
| **5. Political science. Power and politics.** | | | | |
| **5.1** | **Political science. Power and politics (Lec).** Political science. Object, subject, methods of political science. Power and politics. Social functions of political power. Legality and legitimacy of the government | 1 | 2 | UC-5.1, UC- 5.2, UC-3.1, UC-3.2, UC- 6.1, UC-6.2 |
| **5.2** | **Performing practical tasks (Pr).** The subject of political science. The essence and diversity of power. Political power. | 1 | 2 | UC-5.1, UC- 5.2, UC-3.1, UC-3.2, UC- 6.1, UC-6.2 |
| **5.3** | **Preparation for classroom classes (IWS).** Preparation for lectures and practical classes | 1 | 2 | UC-5.1, UC- 5.2, UC-3.1, UC-3.2, UC- 6.1, UC-6.2 |
| **6. The state as an institution of the political system of society.**  **Political ideologies.** | | | | |
| **6.1** | **The state as an institution of the political system of society.**  **Political ideologies. (Lec).** The state as an institution of the political system of society. Political regimes. Forms of government. Forms of the territorial structure of the state. Political ideologies of modernity. Conservatism. Liberalism. Social democratic ideology. Modern radical ideologies. | 1 | 2 | UC-5.1, UC- 5.2, UC-3.1, UC-3.2, UC- 6.1, UC-6.2 |
| **6.2** | **Performing practical tasks (Pr).** Political systems and regimes. The State and civil society. Political ideology. The social functions of ideology and the ideological and political spectrum. Political ideologies of the past and present. | 1 | 2 | UC-5.1, UC- 5.2, UC-3.1, UC-3.2, UC- 6.1, UC-6.2 |

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| **6.3** | **Preparation for classroom classes (IWS).** Preparation for lectures and practical classes | 1 | 2 | UC-5.1, UC- 5.2, UC-3.1, UC-3.2, UC- 6.1, UC-6.2 |
| **7. Political parties and party systems**  **Modern electoral systems** | | | | |
| **7.1** | **Political parties and party systems**  **Modern electoral systems**  **(Lec).** Political parties and party systems. Goals and functions of political parties. Multiparty system as a guarantor of democracy. Party systems. Features of the Russian party system. Electoral systems of modernity. Suffrage. Typology of electoral systems. | 1 | 2 | UC-5.1, UC- 5.2, UC-3.1, UC-3.2, UC- 6.1, UC-6.2 |
| **7.2** | **Performing practical tasks (Pr).** Political parties and party systems. Electoral systems of the present | 1 | 2 | UC-5.1, UC- 5.2, UC-3.1, UC-3.2, UC- 6.1, UC-6.2 |
| **7.3** | **Preparation for classroom classes (IWS).** Preparation for lectures and practical classes | 1 | 2 | UC-5.1, UC- 5.2, UC-3.1, UC-3.2, UC- 6.1, UC-6.2 |
| **8. Political elite and leadership.**  **World politics.** | | | | |
| **8.1** | **Performing practical tasks (Pr).** The political elite. The ruling elite and its role in politics. Political leadership. The modern world political process. International relations of states. Global problems and the role of nation States in their resolution. The role of international organizations in world politics. | 1 | 2 | UC-5.1, UC- 5.2, UC-3.1, UC-3.2, UC- 6.1, UC-6.2 |
| **8.2** | **Preparation for classroom classes (IWS).** Preparation for lectures and practical classes | 1 | 5 | UC-5.1, UC- 5.2, UC-3.1, UC-3.2, UC- 6.1, UC-6.2 |
| **8.3** | **Political elite and leadership.**  **World politics.**  **(Lec).** The political elite and its role in politics. Classical theories of elites. Methods of recruiting elites. Political leadership Functions and styles of activity of a political leader. The modern world political process. International relations. Geopolitical models of the world. | 1 | 2 | UC-5.1, UC- 5.2, UC-3.1, UC-3.2, UC- 6.1, UC-6.2 |
| **9. Intermediate certification (Test)** | | | | |
| **9.1** | **Preparation for the intermediate certification (Test).** | 1 | 17,75 | UC-3.1, UC- 3.2, UC-6.1, UC-6.2 |
| **9.2** | **Contact work with the teacher during the intermediate certification (CWC).** | 1 | 0,25 | UC-3.1, UC- 3.2, UC-6.1, UC-6.2 |

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| **5. EVALUATION MATERIALS** | | | | | |
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| **5.1. List of competencies** | | | | | |
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| List of competencies, the development of which the study of the discipline is aimed at «Sociology», with an indication of the results of their formation in the process of mastering the educational program, presented in paragraph 3 of this work program | | | | | |
| **5.2. Typical control questions and tasks** | | | | | |
| 1. The subject, methods and functions of sociology. Types of sociological theories.  2. Formation and main stages of development of Western sociological thought.  3. The formation and features of Russian sociology.  4. The concept and signs of society. Typology of society. Social progress and regression.  5. Social stratification: historical types and modern understanding.  6. The concept and types of social mobility.  7. Social institutions and their role in public life.  8. Sociology of personality. The concept and structure of personality.  9. Socialization of personality and its forms.  10. Specific sociological research. The main stages and methods of CSI.  11. Political science as a science. The subject, methods, categories and functions of political science.  12. Politics as a social phenomenon: structure, types and functions.  13. The political elite and its functions. Recruiting the elite.  14. Political leadership: the concept, functions and styles of a leader's activity.  15. The political system of society and its elements. Typology of political systems.  16. The state as the main institution of the political system. Features of the state structure of the Russian Federation.  17. Characteristics of a democratic, authoritarian and totalitarian political regime.  18. Political parties and party systems. The specifics of the party system in modern Russia.  19. Political ideologies.  20. Social and political conflicts. Causes of conflicts and ways to resolve them.  21. Features of the modern world political process. | | | | | |
| **5.3. Fund of evaluation Materials** | | | | | |
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| A complete list of evaluation materials is provided in the Appendix 1. | | | | | |
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| **6. MATERIAL, TECHNICAL, EDUCATIONAL AND METHODOLOGICAL SUPPORT OF THE DISCIPLINE (MODULE)** | | | | | |
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| **6.1. MATERIAL AND TECHNICAL SUPPORT OF THE DISCIPLINE (МОДУЛЯ)** | | | | | |
| **Name of premises** | | | | **List of main equipment** | |
| Classroom for lectures and seminars, group and individual consultations, ongoing monitoring and intermediate certification | | | | Multimedia equipment, specialized furniture, sets of demonstration equipment and educational and visual aids that provide thematic illustrations. | |
| A room for independent work of students | | | | Computer equipment with the ability to connect to the Internet and provide access to the electronic information and educational environment of the organization | |
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| **6.2. LIST OF SOFTWARE** | | | | | |
| 1. |  | Microsoft Office. Contract No. 32009183466 from 02.07.2021. | | | |
| 2. |  | Microsoft Windows. Contract No. 32009183466 from 02.07.2021. | | | |

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| **6.3. RECOMMENDED LITERATURE** | | | | |
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| **6.3.1. Basic literature** | | | | |
| 1. |  | Kravchenko A. I. Osnovy sociologii i politologii:uchebnik dlya bakalavrov. - M.: Prospekt, 2015. - 352 s. | | |
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| **6.3.2. Additional literature** | | | | |
| 1. |  | Maslovskij M. V. Sociology politiki: klassicheskie i sovremennye teorii:Ucheb. posobie. - M.: Novyj dom, 2004. - 173 s. | | |
| 2. |  | Gorelov A.A. Osnovy sociologii i politologii:Uchebnoe posobie. - Moscow: Flinta, 2003. - 416 s. | | |
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| **6.4. RECOMMENDED LIST OF MODERN PROFESSIONAL DATABASES AND INFORMATION REFERENCE SYSTEMS** | | | | |
| 1. |  | Scientific Electronic Library http://www.elibrary.ru | | |
| 2. |  | Ministry of Science and Higher Education of the Russian Federation  https://www.minobrnauki.gov.ru | | |
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| **6.5. METHODICAL INSTRUCTIONS FOR STUDENTS STUDYING THE DISCIPLINE (MODULE)** | | | | |
| The student’s independent work is aimed at preparing for academic classes and at developing knowledge, skills and abilities provided for in the discipline program.  In accordance with the curriculum, the discipline may include Lectures, practical classes and Laboratory work, as well as the execution and defense of a course project (work). Successful study of the discipline requires attending all types of classes, completing teacher assignments and familiarization with basic and additional literature. Depending on the activities provided for in the curriculum and section 4 of this program, the student chooses methodological guidelines for independent work from the ones listed below.  When preparing for lecture classes, students need to:  before the next lecture, it is necessary to review the summary of the material of the previous Lectures. If you have difficulties in perceiving the material, you should refer to the main literary sources. If it was not possible to understand the material again, then contact the lecturer (according to the schedule of his consultations) or the teacher in practical classes.  Practical classes complete the study of the most important topics of the discipline. They serve to consolidate the studied material, develop the skills and abilities of preparing reports, messages, gaining experience in oral public speeches, conducting discussions, argumentation and defending the propositions put forward, as well as to monitor the degree of readiness of students in the discipline being studied by the teacher.  When preparing for a practical lesson, students have the opportunity to use the advice of a teacher.  When preparing for practical classes, students need to:  bring with you the literature recommended by the teacher for a specific lesson;  before the next practical lesson on the recommended literary sources, work out the theoretical material corresponding to the topic of the lesson;  at the beginning of classes, ask the teacher questions about the material that caused difficulties in understanding and mastering it when solving tasks set for independent solution;  during the seminar, give specific, clear answers to the substance of the questions;  at the training session, bring each task to the final solution, demonstrate an understanding of the calculations (analyses, situations), in case of difficulties, contact the teacher.  Students who have missed classes (regardless of the reasons), who do not have a written solution to problems or are not prepared for this practical lesson, are recommended to come to the teacher’s consultation no later than 2 weeks and report on the topic studied in the lesson.  The methodological guidelines necessary for studying and passing the discipline are given as part of the educational program. | | | | |

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| **6.6. METHODOLOGICAL RECOMMENDATIONS FOR THE TRAINING OF PERSONS WITH LIMITED HEALTH OPPORTUNITIES AND THE DISABLED** | | |
| The development of the discipline by students with disabilities can be organized both jointly with other students and in separate groups. Special conditions are assumed for students with disabilities to receive education.  The teaching staff gets acquainted with the psychological and physiological characteristics of students with disabilities and persons with disabilities, individual rehabilitation programs for the disabled (if available). If necessary, additional teaching support is provided by tutors, psychologists, social workers, trained assistants.  In accordance with the methodological recommendations of the Ministry of Education and Science of the Russian Federation (approved April 8, 2014 N AK-44/05vn), the course is supposed to use socially active and reflective teaching methods, technologies of socio-cultural rehabilitation in order to assist in establishing full-fledged interpersonal relationships with other students, creating a comfortable psychological climate in the student group. Selection and development of educational materials are made taking into account the provision of material in various forms: auditory, visual, using special technical means and information systems.  Mediamaterials should also be used and adapted taking into account the individual characteristics of the training of persons with disabilities.  The development of the discipline by persons with disabilities is carried out using general and special purpose teaching tools (personal and collective use). Material and technical support provides for the adaptation of classrooms to the needs of persons with disabilities.  The form of certification for students with disabilities is established taking into account individual psychophysical characteristics. For students with HIA, an accessible form of assignment of assessment tools is provided, namely:  - in printed or electronic form (for persons with disorders of the musculoskeletal system);  - in printed or electronic form with enlarged font and contrast (for persons with hearing, speech, vision impairments);  - reading the task aloud by the assistant (for visually impaired persons).  Students with disabilities have increased time to prepare answers to control questions. For such students, an accessible form of providing answers to tasks is provided, namely:  - written on paper or a set of answers on a computer (for persons with hearing and speech impairments);  - choosing an answer from possible options using the services of an assistant (for people with musculoskeletal disorders);  - oral interview (for persons with visual impairments, musculoskeletal system).  If necessary, for students with disabilities, the procedure for evaluating learning outcomes can be carried out in several stages. | | |

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| MINISTRY OF SCIENCE AND HIGHER EDUCATION OF THE RUSSIAN FEDERATION | | | | | | | | | | | | | | | | | | | | | |
| Federal State Budget Educational Institution of Higher Education  «MIREA – Russian Technological University» | | | | | | | | | | | | | | | | | | | | | |
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| **Institute of Physics and Technology** | | | | | | | | | | | | | | | | | | | | | |
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| Working program of the discipline (module) | | | | | | | | | | | | | | | | | | | | | |
| **Technologies for materials engineering** | | | | | | | | | | | | | | | | | | | | | |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  | Department leading the training | | | | | |  |  | **Department of Nanoelectronics** | | | | | | | | | | | | |
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|  | Direction of training | | | | | | |  | **11.04.04 Electronics and nanoelectronics** | | | | | | | | | | | | |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  | Profile | | | | | | |  | **Engineering of modern materials for information technology, renewable energy and sensing** | | | | | | | | | | | | |
|  |  |  |  |  |  |  |  |  |
|  | Qualification | | | | |  |  |  | **Master** | | | | | | | | | | | | |
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|  | Form of education | | | | |  |  |  | **Full-time** | | | | | | | | | |  |  |  |
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|  | Total labor intensity | | | |  |  |  |  | **4 credits** | | | | | | | | | |  |  |  |
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| **Distribution of discipline hours and forms of intermediate certification by semesters** | | | | | | | | | | | | | | | | | | | | | |
| Semester | | Credits | Distribution of hours | | | | | | | | | | | | | | | Forms of intermediate attestation | | |  |
| Total | Lectures | | | | Laboratory work | | | Practical classes | Independent work of students | | Contact work during practice and (or) certification | | | Control of training |  |
| 1 | | 4 | 144 | 16 | | | | 16 | | | 32 | 62 | | 0,25 | | | 17,75 | Test | | |  |
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| The program was made by: |  |  |  |  |
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| *Doctor of Science in Physico-mathematical Sciences, Professor, A. Yurasov\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_* | | | | |
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| Working program of the discipline | | |  |  |
| **Technologies for materials engineering** | | | | |
|  |  |  |  |  |
| it is developed in accordance with FSES HE: | | |  |  |
| Federal State Educational Standard of Higher Education - Magistracy in the Direction of training 11.04.04 Electronics and nanoelectronics (order of the Ministry of Science and Higher Education of the Russian Federation from 22.09.2017. № 959) | | | | |
|  |  |  |  |  |
| it is based on the curriculum: | | |  |  |
| Direction of training: 11.04.04 Electronics and nanoelectronics  Profile: «Engineering of modern materials for information technology, renewable energy and sensing» | | | | |
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| The working program was approved at the meeting of the department | | | | |
| **Department of Nanoelectronics** | | | | |
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| Minutes of meeting from 02.03.2021 № 3  Head of the Department A. Sigov \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ | | | | |

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| **Approval of the WPD for execution in the next academic year** | | | | |
|  |  |  |  |  |
| The working program was revised, discussed and approved for execution in the 2022-2023 academic year at a meeting of the department | | | | |
| **Department of Nanoelectronics** | | | | |
|  |  |  |  |  |
|  | Minutes of meeting from \_\_ \_\_\_\_\_\_\_\_\_\_ 2022. № \_\_  Head of the Department \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ | | | |
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| **Approval of the WPD for execution in the next academic year** | | | | |
|  |  |  |  |  |
| The working program was revised, discussed and approved for execution in the 2023-2024 academic year at a meeting of the department | | | | |
| **Department of Nanoelectronics** | | | | |
|  |  |  |  |  |
|  | Minutes of meeting from \_\_ \_\_\_\_\_\_\_\_\_\_ 2023. № \_\_  Head of the Department \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ | | | |
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| **Approval of the WPD for execution in the next academic year** | | | | |
|  |  |  |  |  |
| The working program was revised, discussed and approved for execution in the 2024-2025 academic year at a meeting of the department | | | | |
| **Department of Nanoelectronics** | | | | |
|  |  |  |  |  |
|  | Minutes of meeting from \_\_ \_\_\_\_\_\_\_\_\_\_ 2024. № \_\_  Head of the Department \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ | | | |
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| **Approval of the WPD for execution in the next academic year** | | | | |
|  |  |  |  |  |
| The working program was revised, discussed and approved for execution in the 2025-2026 academic year at a meeting of the department | | | | |
| **Department of Nanoelectronics** | | | | |
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|  | Minutes of meeting from \_\_ \_\_\_\_\_\_\_\_\_\_ 2025. № \_\_  Head of the Department \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ | | | |
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| **1. OBJECTIVES OF MASTERING THE DISCIPLINE (MODULE)** | | | | | |
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| The discipline «Technologies for materials engineering» aims to contribute to the formation of students’ competencies, provided by this work program in accordance with the requirements of FSES HE in the direction of training 11.04.04 Electronics and nanoelectronics, taking into account the specifics of the profile – «Engineering of modern materials for information technology, renewable energy and sensing». | | | | | |
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| **2. PLACE OF DISCIPLINE (MODULE) IN THE STRUCTURE OF THE EDUCATIONAL PROGRAM** | | | | | |
|  | Direction of training: |  | 11.04.04 Electronics and nanoelectronics | | |
|  |
|  | Profile: |  | Engineering of modern materials for information technology, renewable energy and sensing | | |
|  |  |  |
|  | Block: |  | Disciplines (modules) | | |
|  |  |  |
|  | Part: |  | Mandatory part | | |
|  |  |  |
|  | Total labor intensity: |  | 4 credits (144 academic hours). | | |
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| **3. THE STUDENT’S COMPETENCIES FORMED AS A RESULT OF MASTERING THE DISCIPLINE (MODULE)** | | | | | |
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| As a result of mastering the practice, the student must master the following competencies: | | | | | |
| **GPC-2** - Capable to apply modern research methods, present and argumentatively defend the results of the work performed | | | | | |
| **GPC-3** - Capable to acquire and use new information in its subject area, offer new ideas and approaches to solving engineering problems | | | | | |
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| **PLANNED RESULTS OF TRAINING IN THE DISCIPLINE (MODULE), CHARACTERIZING THE FORMATION OF COMPETENCIES** | | | | | |
|  |  |  |  |  |  |
| **GPC-2 : Capable to apply modern research methods, present and argumentatively defend the results of the work performed** | | | | | |
|  |  |  |  |  |  |
| **GPC-2.1: Applies modern research methods in the field of electronics** | | | | | |
|  |  |  |  |  |  |
| **To know:** | | | | | |
| - basic concepts and patterns in the field of materials science | | | | | |
| **Be able to:** | | | | | |
| - conduct theoretical and experimental research of materials of various nature | | | | | |
| **Possess:** | | | | | |
| - experimental data processing skills | | | | | |
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| **GPC-3 : Capable to acquire and use new information in its subject area, offer new ideas and approaches to solving engineering problems** | | | | | |
|  |  |  |  |  |  |
| **GPC-3.1: Uses new information in the field of electronics** | | | | | |
|  |  |  |  |  |  |
| **To know:** | | | | | |
| - basic physical laws in the field of electronics, regularities of their physical properties | | | | | |
| **Be able to:** | | | | | |
| - analyze the results of scientific research in the field of electronics | | | | | |
| **Possess:** | | | | | |

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| - skills of working on technological installations | | | | | | |
| **GPC-3.2: Offers new ideas and approaches to solving engineering problems in the field of electronics** | | | | | | |
| **To know:** | | | | | | |
| - the main processes of obtaining materials | | | | | | |
| **Be able to:** | | | | | | |
| - set and solve material science problems | | | | | | |
| **Possess:** | | | | | | |
| - skills of using knowledge of physics, mathematics and electronics in solving engineering problems in the field of materials science | | | | | | |
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| **AS A RESULT OF STUDYING THE DISCIPLINE (MODULE), THE STUDENT MUST** | | | | | | |
| **To know:** | | | | | | |
| - the main processes of obtaining materials | | | | | | |
| - basic physical laws in the field of electronics, regularities of their physical properties | | | | | | |
| - basic concepts and patterns in the field of materials science | | | | | | |
| **Be able to:** | | | | | | |
| - set and solve material science problems | | | | | | |
| - analyze the results of scientific research in the field of electronics | | | | | | |
| - conduct theoretical and experimental research of materials of various nature | | | | | | |
| **Possess:** | | | | | | |
| - skills of using knowledge of physics, mathematics and electronics in solving engineering problems in the field of materials science | | | | | | |
| - skills of working on technological installations | | | | | | |
| - experimental data processing skills | | | | | | |
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| **4. STRUCTURE AND CONTENT OF THE DISCIPLINE (MODULE)** | | | | | | |
|  |  |  |  |  |  |  |
| During the training sessions, the organization ensures the development of students’ teamwork skills, interpersonal communication, decision-making and leadership qualities. | | | | | | |
| **Code** | **Name of sections and topics /type of classes/** | | **Semester** | **Academic Hours** | **Competencies** | |
| **1. Technologies for materials engineering** | | | | | | |
| **1.1** | **Lecture** **1. The structure of materials. Defects in the crystal structure.** **(Lec).** Introduction. Technical parameters of materials. Atomic structure of solids. Heteropolar or ionic coupling. Covalent bond. Metal connection. The Van der Waals connection. Features of the atomic-crystal structure. The concept of isotropy and anisotropy. Allotropy or polymorphic transformations. Magnetic transformations. Defects. The structure of the metal ingot. Isotropy of the amorphous state of matter. Amorphization of the substance. | | 1 | 2 | GPC-2.1, GPC -3.1, GPC-3.2 | |

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| **1.2** | **Lecture** **2. Phase transformations. Crystallization. Theory of alloys. Phase equilibrium. Phase state diagrams. (Lec).** Mechanism and regularities of metal crystallization. Conditions for obtaining a fine-grained structure. The structure of the metal ingot. Physical methods of research. The concept of alloys and methods of their production. Features of the structure, crystallization and properties of alloys. Status diagram. Diagrams of the state of two-component alloys. Diagram of the state of alloys. The relationship between the properties of alloys and the type of state diagram. | 1 | 2 | GPC-2.1, GPC -3.1, GPC-3.2 |
| **1.3** | **Lecture** **3. Iron-carbon alloys. Become. Cast iron. (Lec).** Iron-carbon alloys. Diagram of the iron-carbon state. Structures of iron-carbon alloys. Components and phases of iron-carbon alloys. Processes in the structure formation of iron-carbon alloys. Structures of iron-carbon alloys. Become. Classification and marking of steels. Cast iron. Diagram of the iron–graphite state. Structure, properties, classification and labeling of gray cast iron. | 1 | 2 | GPC-2.1, GPC -3.1, GPC-3.2 |
| **1.4** | **Lecture** **4. Non-ferrous metals and alloys based on them.** **(Lec).** Properties of aluminum. Obtaining aluminum. Aluminum alloys. Obtaining and basic properties of magnesium. Magnesium alloys. Industrial use of magnesium alloys. Preparation and basic properties of titanium. Titanium alloys. The use of titanium and its alloys as structural materials. Production and properties of copper. Copper alloys. Industrial use of copper and its alloys. | 1 | 2 | GPC-2.1, GPC -3.1, GPC-3.2 |
| **1.5** | **Lecture** **5. Polymer and ceramic materials. Inorganic glasses and sitalls.** **(Lec).** The concept of polymers and their main characteristics. Synthesis of polymers. Phase and physical states of polymers. Plastics and elastics. Adhesives and sealants. Physico-mechanical and electrical characteristics of polymers. Ceramic materials. Natural and artificial ceramics. The structure of inorganic glasses. Glass. Technological features of obtaining inorganic glasses. The concept of sitalls. The structure of sitalls. Dielectric and physico-mechanical characteristics of sitalls. | 1 | 2 | GPC-2.1, GPC -3.1, GPC-3.2 |

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| **1.6** | **Lecture** **6. Composite materials.** **(Lec).** The concept of composite materials. Classification of composites. The structure of composites. Composites with metal, polymer and inorganic matrices. Strengthening filler. Structures of composite materials. Poly-reinforced composites. Reinforcement efficiency. Methods of obtaining composites. Physical and mechanical properties of composite materials. | 1 | 2 | GPC-2.1, GPC -3.1, GPC-3.2 |
| **1.7** | **Lecture** **7. Structural materials.** **(Lec).** Structural materials. Become. Classification of alloy steels. Classification of structural steels. Hard alloys. | 1 | 2 | GPC-2.1, GPC -3.1, GPC-3.2 |
| **1.8** | **Lecture** **8. Thermal and chemical-thermal treatment of materials. (Lec).** Types of heat treatment of metals. Intermediate transformation. Transformation of austenite into martensite at high cooling rates. Annealing and normalization. Purpose and modes. Chemical and thermal treatment of steel. Cementation. The structure of the cemented layer. Heat treatment after cementation. Nitriding. Cyanidation and nitrocementation. Diffusion metallization. | 1 | 2 | GPC-2.1, GPC -3.1, GPC-3.2 |
| **1.9** | **Performing practical tasks (Pr).** PR 1. Technical parameters of materials (part 1). | 1 | 2 | GPC-3.2 |
| **1.10** | **Performing practical tasks (Pr).** PR 2. Technical parameters of materials (part 2). | 1 | 2 | GPC-3.2 |
| **1.11** | **Performing practical tasks (Pr).** PR 3. Iron–carbon state diagram (part 1). | 1 | 2 | GPC-3.2 |
| **1.12** | **Performing practical tasks (Pr).** PR 4. Iron–carbon state diagram (part 2). | 1 | 2 | GPC-3.2 |
| **1.13** | **Performing practical tasks (Pr).** PR 5. Phase and physical states of polymers (part 1). | 1 | 2 | GPC-3.2 |
| **1.14** | **Performing practical tasks (Pr).** PR 6. Phase and physical states of polymers (part 2). | 1 | 2 | GPC-3.2 |
| **1.15** | **Performing practical tasks (Pr).** PR 7. Influence of alloying elements on transformations in steel (part 1). | 1 | 2 | GPC-3.2 |
| **1.16** | **Performing practical tasks (Pr).** PR 8. Influence of alloying elements on transformations in steel (part 2). | 1 | 2 | GPC-3.2 |
| **1.17** | **Oral interview (Pr).** Control questions based on the materials of the lecture | 1 | 2 | GPC-2.1, GPC -3.1, GPC-3.2 |
| **1.18** | **Oral interview (Pr).** Control questions based on the materials of the lecture | 1 | 2 | GPC-2.1, GPC -3.1, GPC-3.2 |
| **1.19** | **Oral interview (Pr).** Control questions based on the materials of the lecture | 1 | 2 | GPC-2.1, GPC -3.1, GPC-3.2 |

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| **1.20** | **Oral interview (Pr).** Control questions based on the materials of the lecture | | 1 | 2 | GPC-2.1, GPC -3.1, GPC-3.2 | |
| **1.21** | **Oral interview (Pr).** Control questions based on the materials of the lecture | | 1 | 2 | GPC-2.1, GPC -3.1, GPC-3.2 | |
| **1.22** | **Oral interview (Pr).** Control questions based on the materials of the lecture | | 1 | 2 | GPC-2.1, GPC -3.1, GPC-3.2 | |
| **1.23** | **Oral interview (Pr).** Control questions based on the materials of the lecture | | 1 | 2 | GPC-2.1, GPC -3.1, GPC-3.2 | |
| **1.24** | **Solution of the control work (Pr).** Security questions for the section | | 1 | 2 | GPC-2.1, GPC -3.1, GPC-3.2 | |
| **1.25** | **Laboratory work 1.** **(LW).** Phase equilibrium diagrams | | 1 | 4 | GPC-2.1, GPC -3.1 | |
| **1.26** | **Laboratory work 2.** **(LW).** Measurement of mechanical strength of non-ferrous alloys (part 1) | | 1 | 4 | GPC-2.1, GPC -3.1 | |
| **1.27** | **Laboratory work 3.** **(LW).** Measurement of mechanical strength of non-ferrous alloys (part 2) | | 1 | 4 | GPC-2.1, GPC -3.1 | |
| **1.28** | **Laboratory work 4.** **(LW).** Investigation of the strength of the adhesive joint. | | 1 | 4 | GPC-2.1, GPC -3.1 | |
| **1.29** | **Homework (IWS).** Search for new information on a given topic. | | 1 | 30 | GPC-2.1 | |
| **1.30** | **Preparation for classroom classes (IWS).** Preparation for lectures, practical and laboratory work. | | 1 | 32 | GPC-2.1, GPC -3.2, GPC-3.1 | |
| **2. Intermediate certification (Test)** | | | | | | |
| **2.1** | **Preparation for the intermediate certification (Test).** | | 1 | 17,75 | GPC-2.1, GPC -3.1, GPC-3.2 | |
| **2.2** | **Contact work with the teacher during the intermediate certification (CWC).** | | 1 | 0,25 | GPC-2.1, GPC -3.1, GPC-3.2 | |
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| **5. EVALUATION MATERIALS** | | | | | | |
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| **5.1. List of competencies** | | | | | | |
| List of competencies, the development of which the study of the discipline is aimed at «Technologies for materials engineering», with an indication of the results of their formation in the process of mastering the educational program, presented in paragraph 3 of this work program | | | | | | |
| **5.2. Typical control questions and tasks** | | | | | | |
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| - Interatomic interaction, the effect of the energy of interatomic interaction on the properties of materials.  - Types of chemical bonds between atoms.  - The influence of the type of bond on the properties of materials.  - Cell parameters.  - The main types of crystal lattices.  - Anisotropy of crystals. Polymorphism.  - Indexes of crystal planes and directions.  - Defects in the structure of real crystals.  - The concept of alloys, system, components and phases.  - Solid solutions, mechanical mixtures, chemical compounds.  - Crystallization. Physical nature of metal crystallization.  - Mechanism and kinetics of crystallization: nucleation and growth of crystals. | | | | | | |

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| - Factors affecting the crystallization process.  - Shape and size of crystals.  - The structure of metal ingots.  - Diagrams of the state of alloys.  - The relationship between the structure and properties of alloys.  - Heat treatment of metal materials.  - Types of heat treatment and their purpose, the choice of heat treatment modes.  - Electrical properties of conductors.  - The influence of the material structure on the electrical resistivity.  - Temperature coefficient of electrical resistivity.  - Contact potential difference and its practical use.  - Materials of high electrical conductivity,  - Physical and economic criteria for the selection of materials of high electrical conductivity.  - Electrical cleaning and aging of dielectrics.  - Experimental methods for determining volumetric and surface resistance.  - Polarization of dielectrics.  - Types of polarization, features of elastic and relaxation polarization.  - Mechanisms of polarization.  - Electronic, ionic, dipole and spontaneous polarization.  - The influence of temperature and frequency of the electric field on the dielectric permittivity.  - Practical application of dielectrics with various types and mechanisms of polarization.  - Dielectric losses. | | | | | |
| **5.3. Fund of evaluation Materials** | | | | | |
| A complete list of evaluation materials is provided in the Appendix 1. | | | | | |
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| **6. MATERIAL, TECHNICAL, EDUCATIONAL AND METHODOLOGICAL SUPPORT OF THE DISCIPLINE (MODULE)** | | | | | |
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| **6.1. MATERIAL AND TECHNICAL SUPPORT OF THE DISCIPLINE (МОДУЛЯ)** | | | | | |
| **Name of premises** | | | | **List of main equipment** | |
| Classroom for lectures and seminars, group and individual consultations, ongoing monitoring and intermediate certification | | | | Multimedia equipment, specialized furniture, sets of demonstration equipment and educational and visual aids that provide thematic illustrations. | |
| Specialized educational laboratory of materials | | | | Laboratory installations: 1-study of the properties of magnetic materials (4 types), 2 - study of the properties of ferroelectrics (2 types), 3 - study of the properties of electronic equipment elements (3 types), 4 - study of the properties of microelectronics devices (2 types). | |
| A room for independent work of students | | | | Computer equipment with the ability to connect to the Internet and provide access to the electronic information and educational environment of the organization. | |
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| **6.2. LIST OF SOFTWARE** | | | | | |
| 1. |  | Microsoft Windows. Contract No. 32009183466 from 02.07.2021. | | | |
| 2. |  | Microsoft Office. Contract No. 32009183466 from 02.07.2021. | | | |

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| **6.3. RECOMMENDED LITERATURE** | | | | |
|  |  |  |  |  |
| **6.3.1. Basic literature** | | | | |
| 1. |  | Blanter M. S., Sundeev R. V. Materialovedenie nanostrukturirovannyh materialov [Electronic resource]:praktikum. - M.: RTU MIREA, 2018. - – Access mode: http://library.mirea.ru/secret/25092018/1792.iso | | |
| 2. |  | Kondratenko V. S., Kobysh A. N. Innovacionnoe materialovedenie [Electronic resource]:uchebnoe posobie. - M.: RTU MIREA, 2018. - – Access mode: http://library.mirea.ru/secret/06032019/1978.iso | | |
| 3. |  | Zemskov YU. P. Materialovedenie [Electronic resource]:uchebnoe posobie. - Sankt- Peterburg: Lan', 2019. - 188 s. – Access mode: https://e.lanbook.com/book/113910 | | |
| 4. |  | Sapunov S. V. Materialovedenie [Electronic resource]:. - Sankt-Peterburg: Lan', 2021. - 208 s. – Access mode: https://e.lanbook.com/book/168740 | | |
| 5. |  | Bondarenko G. G., Kabanova T. A., Rybalko V. V. Materialovedenie [Electronic resource]:Uchebnik dlya vuzov. - Moscow: YUrajt, 2021. - 327 s – Access mode: https://urait.ru/bcode/468630 | | |
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| **6.3.2. Additional literature** | | | | |
| 1. |  | Buryj G. G. Materialovedenie. Tekhnologiya konstrukcionnyh materialov [Electronic resource]:uchebno-metodicheskoe posobie. - Omsk: SibADI, 2019. - 222 s. – Access mode: https://e.lanbook.com/book/149463 | | |
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| **6.4. RECOMMENDED LIST OF MODERN PROFESSIONAL DATABASES AND INFORMATION REFERENCE SYSTEMS** | | | | |
| 1. |  | Materials Science Information Portal http://www.materialstoday.com | | |
| 2. |  | Website of the PTI Department of Nanoelectronics https://fks.mirea.ru | | |
| 3. |  | Website of the Federal Service for Intellectual Property, Patents and Trademarks  http://www.fips.ru/ | | |
| 4. |  | Database Web of Science  http://www.webofknowledge.com | | |
| 5. |  | National Research Center «Kurchatov Institute»  http://www.kcsni.nrcki.ru | | |
| 6. |  | An international resource for the search and exchange of scientific publications  https://www.researchgate.net | | |
| 7. |  | Elektronika NTB - scientific and technical journal  http://www.electronics.ru | | |
| 8. |  | Information and reference portal of scientific publications of domestic and foreign authors «Google Academy»  https://www.scholar.google.ru | | |
| 9. |  | Russian Technological Journal  https://www.rtj.mirea.ru | | |
| 10. |  | Information portal of the International Citation System Scopus  https://www.scopus.com | | |
| 11. |  | Information portal of the International Citation System «Web of Science”  https://www.apps.webofknowledge.com | | |
| 12. |  | Foundation for the Promotion of Innovation  http://www.fasie.ru | | |
| 13. |  | Ministry of Science and Higher Education of the Russian Federation  https://www.minobrnauki.gov.ru | | |

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| 14. |  | Natural Science educational Portal http://www.en.edu.ru | | |
| 15. |  | Scientific Electronic Library http://www.elibrary.ru | | |
| 16. |  | Information portal of the Russian Science Foundation http://www.rscf.ru | | |
| 17. |  | Russian Foundation for Basic Research https://www.rfbr.ru | | |
| 18. |  | Information portal «Popular nanotechnologies» http://www.popnano.ru | | |
| 19. |  | Nanometer - Nanotechnology community http://www.nanometer.ru | | |
| 20. |  | NanoNewsNet.ru- non-commercial on-line publication dedicated to the nanoindustry http://www.old.nanonewsnet.ru | | |
| 21. |  | Electronic fund of legal and regulatory technical documentation Tekhnoexpert http://www.docs.cntd.ru | | |
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| **6.5. METHODICAL INSTRUCTIONS FOR STUDENTS STUDYING THE DISCIPLINE (MODULE)** | | | | |
| The student’s independent work is aimed at preparing for academic classes and at developing knowledge, skills and abilities provided for in the discipline program.  In accordance with the curriculum, the discipline may include Lectures, practical classes and Laboratory work, as well as the execution and defense of a course project (work). Successful study of the discipline requires attending all types of classes, completing teacher assignments and familiarization with basic and additional literature. Depending on the activities provided for in the curriculum and section 4 of this program, the student chooses methodological guidelines for independent work from the ones listed below.  When preparing for lecture classes, students need to:  before the next lecture, it is necessary to review the summary of the material of the previous Lectures. If you have difficulties in perceiving the material, you should refer to the main literary sources. If it was not possible to understand the material again, then contact the lecturer (according to the schedule of his consultations) or the teacher in practical classes.  Practical classes complete the study of the most important topics of the discipline. They serve to consolidate the studied material, develop the skills and abilities of preparing reports, messages, gaining experience in oral public speeches, conducting discussions, argumentation and defending the propositions put forward, as well as to monitor the degree of readiness of students in the discipline being studied by the teacher.  When preparing for a practical lesson, students have the opportunity to use the advice of a teacher.  When preparing for practical classes, students need to:  bring with you the literature recommended by the teacher for a specific lesson;  before the next practical lesson on the recommended literary sources, work out the theoretical material corresponding to the topic of the lesson;  at the beginning of classes, ask the teacher questions about the material that caused difficulties in understanding and mastering it when solving tasks set for independent solution;  during the seminar, give specific, clear answers to the substance of the questions;  at the training session, bring each task to the final solution, demonstrate an understanding of the calculations (analyses, situations), in case of difficulties, contact the teacher.  Students who have missed classes (regardless of the reasons), who do not have a written solution to problems or are not prepared for this practical lesson, are recommended to come to the teacher’s consultation no later than 2 weeks and report on the topic studied in the lesson.  The methodological guidelines necessary for studying and passing the discipline are given as part of the educational program. | | | | |
| **6.6. METHODOLOGICAL RECOMMENDATIONS FOR THE TRAINING OF PERSONS WITH LIMITED HEALTH OPPORTUNITIES AND THE DISABLED** | | | | |
| The development of the discipline by students with disabilities can be organized both jointly with other students and in separate groups. | | | | |

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| Special conditions are assumed for students with disabilities to receive education.  The teaching staff gets acquainted with the psychological and physiological characteristics of students with disabilities and persons with disabilities, individual rehabilitation programs for the disabled (if available). If necessary, additional teaching support is provided by tutors, psychologists, social workers, trained assistants.  In accordance with the methodological recommendations of the Ministry of Education and Science of the Russian Federation (approved April 8, 2014 N AK-44/05vn), the course is supposed to use socially active and reflective teaching methods, technologies of socio-cultural rehabilitation in order to assist in establishing full-fledged interpersonal relationships with other students, creating a comfortable psychological climate in the student group. Selection and development of educational materials are made taking into account the provision of material in various forms: auditory, visual, using special technical means and information systems.  Mediamaterials should also be used and adapted taking into account the individual characteristics of the training of persons with disabilities.  The development of the discipline by persons with disabilities is carried out using general and special purpose teaching tools (personal and collective use). Material and technical support provides for the adaptation of classrooms to the needs of persons with disabilities.  The form of certification for students with disabilities is established taking into account individual psychophysical characteristics. For students with HIA, an accessible form of assignment of assessment tools is provided, namely:  - in printed or electronic form (for persons with disorders of the musculoskeletal system);  - in printed or electronic form with enlarged font and contrast (for persons with hearing, speech, vision impairments);  - reading the task aloud by the assistant (for visually impaired persons).  Students with disabilities have increased time to prepare answers to control questions. For such students, an accessible form of providing answers to tasks is provided, namely:  - written on paper or a set of answers on a computer (for persons with hearing and speech impairments);  - choosing an answer from possible options using the services of an assistant (for people with musculoskeletal disorders);  - oral interview (for persons with visual impairments, musculoskeletal system).  If necessary, for students with disabilities, the procedure for evaluating learning outcomes can be carried out in several stages. |

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| MINISTRY OF SCIENCE AND HIGHER EDUCATION OF THE RUSSIAN FEDERATION | | | | | | | | | | | | | | | | | | | | | |
| Federal State Budget Educational Institution of Higher Education  «MIREA – Russian Technological University» | | | | | | | | | | | | | | | | | | | | | |
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| Working program of the discipline (module) | | | | | | | | | | | | | | | | | | | | | |
| **Personal growth technologies** | | | | | | | | | | | | | | | | | | | | | |
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|  | Department leading the training | | | | | |  |  | **Department of Modern Management Technologies** | | | | | | | | | | | | |
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|  | Direction of training | | | | | | |  | **11.04.04 Electronics and nanoelectronics** | | | | | | | | | | | | |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  | Profile | | | | | | |  | **Engineering of modern materials for information technology, renewable energy and sensing** | | | | | | | | | | | | |
|  |  |  |  |  |  |  |  |  |
|  | Qualification | | | | |  |  |  | **Master** | | | | | | | | | | | | |
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|  | Form of education | | | | |  |  |  | **Full-time** | | | | | | | | | |  |  |  |
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|  | Total labor intensity | | | |  |  |  |  | **2 credits** | | | | | | | | | |  |  |  |
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| **Distribution of discipline hours and forms of intermediate certification by semesters** | | | | | | | | | | | | | | | | | | | | | |
| Semester | | Credits | Distribution of hours | | | | | | | | | | | | | | | Forms of intermediate attestation | | |  |
| Total | Lectures | | | | Laboratory work | | | Practical classes | Independent work of students | | Contact work during practice and (or) certification | | | Control of training |  |
| 2 | | 2 | 72 | 16 | | | | 0 | | | 16 | 22 | | 0,25 | | | 17,75 | Test | | |  |
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| The program was made by: |  |  |  |  |
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| *Ph.D. Psychological Sciences, Associate Professor, A. Bykova \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_* | | | | |
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| Working program of the discipline | | |  |  |
| **Personal growth technologies** | | | | |
|  |  |  |  |  |
| it is developed in accordance with FSES HE: | | |  |  |
| Federal State Educational Standard of Higher Education - Magistracy in the Direction of training 11.04.04 Electronics and nanoelectronics (order of the Ministry of Science and Higher Education of the Russian Federation from 22.09.2017. № 959) | | | | |
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| it is based on the curriculum: | | |  |  |
| Direction of training: 11.04.04 Electronics and nanoelectronics  Profile: «Engineering of modern materials for information technology, renewable energy and sensing» | | | | |
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| The working program was approved at the meeting of the department | | | | |
| **Department of Modern Management Technologies** | | | | |
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| Minutes of meeting from 27.03.2021 № 1  Head of the Department D. Denisov \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ | | | | |

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| **Approval of the WPD for execution in the next academic year** | | | | |
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| The working program was revised, discussed and approved for execution in the 2022-2023 academic year at a meeting of the department | | | | |
| **Department of Modern Management Technologies** | | | | |
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|  | Minutes of meeting from \_\_ \_\_\_\_\_\_\_\_\_\_ 2022. № \_\_  Head of the Department \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ | | | |
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| **Approval of the WPD for execution in the next academic year** | | | | |
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| The working program was revised, discussed and approved for execution in the 2023-2024 academic year at a meeting of the department | | | | |
| **Department of Modern Management Technologies** | | | | |
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|  | Minutes of meeting from \_\_ \_\_\_\_\_\_\_\_\_\_ 2023. № \_\_  Head of the Department \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ | | | |
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| **Approval of the WPD for execution in the next academic year** | | | | |
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| The working program was revised, discussed and approved for execution in the 2024-2025 academic year at a meeting of the department | | | | |
| **Department of Modern Management Technologies** | | | | |
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|  | Minutes of meeting from \_\_ \_\_\_\_\_\_\_\_\_\_ 2024. № \_\_  Head of the Department \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ | | | |
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| **Approval of the WPD for execution in the next academic year** | | | | |
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| The working program was revised, discussed and approved for execution in the 2025-2026 academic year at a meeting of the department | | | | |
| **Department of Modern Management Technologies** | | | | |
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|  | Minutes of meeting from \_\_ \_\_\_\_\_\_\_\_\_\_ 2025. № \_\_  Head of the Department \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ | | | |
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| **1. OBJECTIVES OF MASTERING THE DISCIPLINE (MODULE)** | | | | | |
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| The discipline «Personal growth technologies» aims to contribute to the formation of students’ competencies, provided by this work program in accordance with the requirements of FSES HE in the direction of training 11.04.04 Electronics and nanoelectronics, taking into account the specifics of the profile – «Engineering of modern materials for information technology, renewable energy and sensing». | | | | | |
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| **2. PLACE OF DISCIPLINE (MODULE) IN THE STRUCTURE OF THE EDUCATIONAL PROGRAM** | | | | | |
|  | Direction of training: |  | 11.04.04 Electronics and nanoelectronics | | |
|  |
|  | Profile: |  | Engineering of modern materials for information technology, renewable energy and sensing | | |
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|  | Block: |  | Disciplines (modules) | | |
|  |  |  |
|  | Part: |  | Mandatory part | | |
|  |  |  |
|  | Total labor intensity: |  | 2 credits (72 academic hours). | | |
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| **3. THE STUDENT’S COMPETENCIES FORMED AS A RESULT OF MASTERING THE DISCIPLINE (MODULE)** | | | | | |
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| As a result of mastering the practice, the student must master the following competencies: | | | | | |
| **UC-6** - Capable to determine and implement the priorities of his own activities and ways to improve it based on self-assessment | | | | | |
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| **PLANNED RESULTS OF TRAINING IN THE DISCIPLINE (MODULE), CHARACTERIZING THE FORMATION OF COMPETENCIES** | | | | | |
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| **UC-6 : Capable to determine and implement the priorities of his own activities and ways to improve it based on self-assessment** | | | | | |
|  |  |  |  |  |  |
| **UC-6.1: Assesses his resources and their limits (personal, situational, temporary) for the successful completion of the assigned task** | | | | | |
| **To know:** | | | | | |
| - the main theoretical and methodological approaches and technologies of personal growth; the main theoretical and methodological approaches in the research of professional activity | | | | | |
| **Be able to:** | | | | | |
| - conduct self-analysis and self-assessment; determine the priorities of their own professional activities; apply critical thinking to evaluate ways and means of improving their own professional activities | | | | | |
|  |  |  |  |  |  |
| **UC-6.2: Defines educational needs and ways to improve one’s own (including professional) activities based on self-assessment** | | | | | |
| **To know:** | | | | | |
| - features of the formation of professional interest and educational motivation; the basics of self-reflection and self-knowledge; own professional interests and needs, own professional and personal resources | | | | | |
| **Be able to:** | | | | | |
| - systematize professional knowledge in order to write a plan-project of professional activity; to determine the priorities of professional growth | | | | | |
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| **AS A RESULT OF STUDYING THE DISCIPLINE (MODULE), THE STUDENT MUST** | | | | | |

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| **To know:** | | | | | | |
| - features of the formation of professional interest and educational motivation; the basics of self-reflection and self-knowledge; own professional interests and needs, own professional and personal resources | | | | | | |
| - the main theoretical and methodological approaches and technologies of personal growth; the main theoretical and methodological approaches in the research of professional activity | | | | | | |
| **Be able to:** | | | | | | |
| - systematize professional knowledge in order to write a plan-project of professional activity; to determine the priorities of professional growth | | | | | | |
| - conduct self-analysis and self-assessment; determine the priorities of their own professional activities; apply critical thinking to evaluate ways and means of improving their own professional activities | | | | | | |
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| **4. STRUCTURE AND CONTENT OF THE DISCIPLINE (MODULE)** | | | | | | |
|  |  |  |  |  |  |  |
| During the training sessions, the organization ensures the development of students’ teamwork skills, interpersonal communication, decision-making and leadership qualities. | | | | | | |
| **Code** | **Name of sections and topics /type of classes/** | | **Semester** | **Academic Hours** | **Competencies** | |
| **1. Fundamentals of professional and personal growth and self-development** | | | | | | |
| **1.1** | **Self-development and personal growth (Lec).** Self-development and self-organization of personality: problems of definition, main components and aspects. Problems of personal and professional development. Personal and professional qualities. Interaction of a person and a professional organization. Personality-centered approach and technologies of personality development | | 2 | 2 | UC-6.1 | |
| **1.2** | **Performing practical tasks (Pr).** Opportunities and Personal growth technologies | | 2 | 2 | UC-6.1 | |
| **1.3** | **Personal growth as a condition of professional success (Lec).** Personal growth: criteria, signs. The wheel of life balance. How to find and choose your field of professional activity. Formation of the foundation for personal and professional growth. The role of character, a system of own principles and values. Study of practical methods of self-improvement of self-esteem and stress resistance | | 2 | 2 | UC-6.1 | |
| **1.4** | **Performing practical tasks (Pr).** Types of personalities and their opportunities in the workforce | | 2 | 2 | UC-6.1 | |
| **1.5** | **Effective communication in professional activity (Lec).** Influence skills without authority. Line of argument. The ladder of conflict. Non-standard chefs. Toxic people. Resolve the conflict. Strong questions | | 2 | 2 | UC-6.2 | |

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| **1.6** | **Performing practical tasks (Pr).** Principles of building constructive relationships | 2 | 2 | UC-6.2 |
| **1.7** | **Intellectual and emotional component of professional activity** **(Lec).** Cognitive effectiveness: a holistic approach. Theory and myths about efficiency. Biological bases of efficiency. Awareness and expansion of the focus of attention as the basis of effectiveness  Intellectual and emotional components of control over events that occur in life. Emotional Intelligence | 2 | 2 | UC-6.2 |
| **1.8** | **Performing practical tasks (Pr).** Awareness skills | 2 | 2 | UC-6.2 |
| **1.9** | **Willpower and motivation (Lec).** Neurotransmitters of motivation. What is "external" motivation and how it is useful. Nutrition and "self-monitoring windows"‎. The power of a positive example for the "weak-willed"‎. What a really useful time management. What is the danger of the "new life from Monday»? How to awaken motivation at the brain level | 2 | 2 | UC-6.1 |
| **1.10** | **Performing practical tasks (Pr).** Will, motivation and self-control | 2 | 2 | UC-6.1 |
| **1.11** | **Interaction in groups (Lec).** Live commands. Stress management in projects. Managing people and projects in the modern world. Problems of modern management. The idea of project management. People are living systems. Team formation | 2 | 2 | UC-6.1 |
| **1.12** | **Performing practical tasks (Pr).** Structure and principles of interaction in small groups | 2 | 2 | UC-6.1 |
| **1.13** | **Creativity and facilitation (Lec).** Synectic. Design thinking. Craft. 6 servants. RTV. Lateral thinking. Causal analysis. A snowball. DARIZ | 2 | 2 | UC-6.2 |
| **1.14** | **Performing practical tasks (Pr).** Creative management | 2 | 2 | UC-6.2 |
| **1.15** | **Defining life strategies (Lec).** Value orientations. A life choice. Life planning. Time perspectives. Definition of life strategies. Self-learning strategies. Coaching tools for getting out of a mental stupor. Self-management | 2 | 2 | UC-6.2 |
| **1.16** | **Writing an essay (Pr).** Problems of personal self-realization in modern society | 2 | 2 | UC-6.2 |
| **1.17** | **Preparation for classroom classes (IWS).** | 2 | 22 | UC-6.1, UC-6.2 |

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| **2. Intermediate certification (Test)** | | | | | | |
| **2.1** | **Preparation for the intermediate certification (Test).** | | 2 | 17,75 | UC-6.1, UC-6.2 | |
| **2.2** | **Contact work with the teacher during the intermediate certification (CWC).** | | 2 | 0,25 | UC-6.1, UC-6.2 | |
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| **5. EVALUATION MATERIALS** | | | | | | |
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| **5.1. List of competencies** | | | | | | |
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| List of competencies, the development of which the study of the discipline is aimed at «Personal growth technologies», with an indication of the results of their formation in the process of mastering the educational program, presented in paragraph 3 of this work program | | | | | | |
| **5.2. Typical control questions and tasks** | | | | | | |
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| 1. What is the essence of personal growth of a manager?  2. Verbal communication (optimal use of speech means).  3. Types of communication: cognitive communication; persuasive communication.  4. Will as the highest level of human regulation. Strong-willed personality qualities.  5. Identify and justify the skills of setting individual and professional goals.  6. Identify and justify the success factors in life.  7. Identify the psychological foundations that affect the level and quality of life.  8. Highlight the secrets and techniques of effective communication, persuasion and influence.  9. Group characteristics.  10. Life path: concept, stages.  11. What basic principles and laws underlie high achievements.  12. What does the intellectual and emotional components of control over events that occur in a person's life have to do with the performance of work functions?  13. Classification of groups.  14. Classification and characteristics of informal groups.  15. Personal growth and self-development: concept, techniques and strategies.  16. Personality as an object of various sciences. The concept of "person", "individual", "personality", "subject", "activity".  17. Methods of self-improvement of self-esteem and stress resistance.  18. What are the main mechanisms of cognition of another person in the process of communication. Give examples.  19. General characteristics of personality components responsible for self-regulation and individuality. Personality profile.  20. Describe the possibilities of using the wheel of life balance for personal growth.  21. The main areas of personality formation: activity, communication, self-awareness.  22. Describe the communicative side of communication. Give examples of communication barriers.  23. Describe the role of the subconscious mind for personal growth and success.  24. Describe the fears and complexes that interfere with work and life, how to overcome them and gain confidence.  25. Evaluate the role of appearance in influencing perception.  26. The concept of informal groups (organizations).  27. Concepts of group, team, project team.  28. The nature and typology of nonverbal communication.  29. Professional growth: concept, resources.  30. Psychological structure of personality.  31. Psychological aspects of the formation of formal and informal organizations.  32. Development, mechanism of formation of formal and informal organizations.  33. Reveal the role of character, the system of your own principles and values in achieving success. | | | | | | |

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| 34. Reveal the essence of psychological well-being of a modern person.  35. Abilities and inclinations.  36. Does emotional intelligence exist? Justify your answer.  37. Formulate practical recommendations to increase energy, increase efficiency, strengthen resources and funds.  38. Formulate techniques for managing your resources and practices for  39. Technology and methods of effective employment  40. Types of temperament, their physiological basis and psychological characteristics.  41. Factors affecting the effectiveness of the group.  42. Formal groups (organizations), their types and features.  43. Communication functions: communicative, interactive, perceptual.  44. Character and its structure. Character accentuation. The connection of temperament and character.  45. Characteristics of groups according to the criterion of operability.  46. What does the concept of "active listening" mean? Give examples of how to listen and how not to listen.  47. What contributes to the achievement of an effective choice of one's field of professional activity.  48. Emotions and feelings: concept, types, properties, functions, mechanisms of formation. Emotion management. | | | | | |
| **5.3. Fund of evaluation Materials** | | | | | |
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| A complete list of evaluation materials is provided in the Appendix 1. | | | | | |
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| **6. MATERIAL, TECHNICAL, EDUCATIONAL AND METHODOLOGICAL SUPPORT OF THE DISCIPLINE (MODULE)** | | | | | |
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| **6.1. MATERIAL AND TECHNICAL SUPPORT OF THE DISCIPLINE (МОДУЛЯ)** | | | | | |
| **Name of premises** | | | | **List of main equipment** | |
| Classroom for lectures and seminars, group and individual consultations, ongoing monitoring and intermediate certification | | | | Multimedia equipment, specialized furniture, sets of demonstration equipment and educational and visual aids that provide thematic illustrations. | |
| A room for independent work of students | | | | Computer equipment with the ability to connect to the Internet and provide access to the electronic information and educational environment of the organization. | |
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| **6.2. LIST OF SOFTWARE** | | | | | |
| 1. |  | Microsoft Windows. Contract No. 32009183466 from 02.07.2021. | | | |
| 2. |  | Microsoft Office. Contract No. 32009183466 from 02.07.2021. | | | |
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| **6.3. RECOMMENDED LITERATURE** | | | | | |
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| **6.3.1. Basic literature** | | | | | |
| 1. |  | Zobkov V. A. Metodologiya lichnostnogo razvitiya [Electronic resource]:Uchebnoe posobie dlya vuzov. - Moscow: YUrajt, 2021. - 172 s – Access mode: https://urait.ru/bcode/477209 | | | |
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| **6.3.2. Additional literature** | | | | | |
| 1. |  | Kavun L. V. Psihologiya lichnosti. Teorii zarubezhnyh psihologov [Electronic resource]:Uchebnoe posobie dlya vuzov. - Moscow: YUrajt, 2021. - 109 s – Access mode: https://urait.ru/bcode/472071 | | | |

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| 2. |  | Glozman ZH. M. Psihologiya. Obshchenie i zdorov'e lichnosti [Electronic resource]:Uchebnoe posobie dlya vuzov. - Moscow: YUrajt, 2021. - 193 s – Access mode: https://urait.ru/bcode/472262 | | |
| 3. |  | Eliseev O. P. Praktikum po psihologii lichnosti [Electronic resource]:Uchebnik dlya vuzov. - Moscow: YUrajt, 2021. - 390 s – Access mode: https://urait.ru/bcode/471972 | | |
| 4. |  | CHernyshev A. S., Sarychev S. V. Social'naya psihologiya lichnosti i gruppy [Electronic resource]:Uchebnoe posobie dlya vuzov. - Moscow: YUrajt, 2021. - 201 s – Access mode: https://urait.ru/bcode/477204 | | |
| 5. |  | Ramendik D. M. Trening lichnostnogo rosta [Electronic resource]:Uchebnik i praktikum dlya vuzov. - Moscow: YUrajt, 2021. - 136 s – Access mode: https://urait.ru/bcode/470461 | | |
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| **6.4. RECOMMENDED LIST OF MODERN PROFESSIONAL DATABASES AND INFORMATION REFERENCE SYSTEMS** | | | | |
| 1. |  | Consultant Plus http:// www.consultant.ru | | |
| 2. |  | Ministry of Science and Higher Education of the Russian Federation  https://www.minobrnauki.gov.ru | | |
| 3. |  | Information and legal portal GARANT http:// www.garant.ru | | |
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| **6.5. METHODICAL INSTRUCTIONS FOR STUDENTS STUDYING THE DISCIPLINE (MODULE)** | | | | |
| The student’s independent work is aimed at preparing for academic classes and at developing knowledge, skills and abilities provided for in the discipline program.  In accordance with the curriculum, the discipline may include Lectures, practical classes and Laboratory work, as well as the execution and defense of a course project (work). Successful study of the discipline requires attending all types of classes, completing teacher assignments and familiarization with basic and additional literature. Depending on the activities provided for in the curriculum and section 4 of this program, the student chooses methodological guidelines for independent work from the ones listed below.  When preparing for lecture classes, students need to:  before the next lecture, it is necessary to review the summary of the material of the previous Lectures. If you have difficulties in perceiving the material, you should refer to the main literary sources. If it was not possible to understand the material again, then contact the lecturer (according to the schedule of his consultations) or the teacher in practical classes.  Practical classes complete the study of the most important topics of the discipline. They serve to consolidate the studied material, develop the skills and abilities of preparing reports, messages, gaining experience in oral public speeches, conducting discussions, argumentation and defending the propositions put forward, as well as to monitor the degree of readiness of students in the discipline being studied by the teacher.  When preparing for a practical lesson, students have the opportunity to use the advice of a teacher.  When preparing for practical classes, students need to:  bring with you the literature recommended by the teacher for a specific lesson;  before the next practical lesson on the recommended literary sources, work out the theoretical material corresponding to the topic of the lesson;  at the beginning of classes, ask the teacher questions about the material that caused difficulties in understanding and mastering it when solving tasks set for independent solution;  during the seminar, give specific, clear answers to the substance of the questions;  at the training session, bring each task to the final solution, demonstrate an understanding of the calculations (analyses, situations), in case of difficulties, contact the teacher.  Students who have missed classes (regardless of the reasons), who do not have a written solution to problems or are not prepared for this practical lesson, are recommended to come to the teacher's consultation no later than 2 weeks and report on the topic studied in the lesson. | | | | |

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| The methodological guidelines necessary for studying and passing the discipline are given as part of the educational program. | | |
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| **6.6. METHODOLOGICAL RECOMMENDATIONS FOR THE TRAINING OF PERSONS WITH LIMITED HEALTH OPPORTUNITIES AND THE DISABLED** | | |
| The development of the discipline by students with disabilities can be organized both jointly with other students and in separate groups. Special conditions are assumed for students with disabilities to receive education.  The teaching staff gets acquainted with the psychological and physiological characteristics of students with disabilities and persons with disabilities, individual rehabilitation programs for the disabled (if available). If necessary, additional teaching support is provided by tutors, psychologists, social workers, trained assistants.  In accordance with the methodological recommendations of the Ministry of Education and Science of the Russian Federation (approved April 8, 2014 N AK-44/05vn), the course is supposed to use socially active and reflective teaching methods, technologies of socio-cultural rehabilitation in order to assist in establishing full-fledged interpersonal relationships with other students, creating a comfortable psychological climate in the student group. Selection and development of educational materials are made taking into account the provision of material in various forms: auditory, visual, using special technical means and information systems.  Mediamaterials should also be used and adapted taking into account the individual characteristics of the training of persons with disabilities.  The development of the discipline by persons with disabilities is carried out using general and special purpose teaching tools (personal and collective use). Material and technical support provides for the adaptation of classrooms to the needs of persons with disabilities.  The form of certification for students with disabilities is established taking into account individual psychophysical characteristics. For students with HIA, an accessible form of assignment of assessment tools is provided, namely:  - in printed or electronic form (for persons with disorders of the musculoskeletal system);  - in printed or electronic form with enlarged font and contrast (for persons with hearing, speech, vision impairments);  - reading the task aloud by the assistant (for visually impaired persons).  Students with disabilities have increased time to prepare answers to control questions. For such students, an accessible form of providing answers to tasks is provided, namely:  - written on paper or a set of answers on a computer (for persons with hearing and speech impairments);  - choosing an answer from possible options using the services of an assistant (for people with musculoskeletal disorders);  - oral interview (for persons with visual impairments, musculoskeletal system).  If necessary, for students with disabilities, the procedure for evaluating learning outcomes can be carried out in several stages. | | |

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| Federal State Budget Educational Institution of Higher Education  «MIREA – Russian Technological University» | | | | | | | | | | | | | | | | | | | | | |
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| Working program of the discipline (module) | | | | | | | | | | | | | | | | | | | | | |
| **Physics of the solid state** | | | | | | | | | | | | | | | | | | | | | |
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|  | Department leading the training | | | | | |  |  | **Department of Nanoelectronics** | | | | | | | | | | | | |
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|  | Direction of training | | | | | | |  | **11.04.04 Electronics and nanoelectronics** | | | | | | | | | | | | |
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|  | Profile | | | | | | |  | **Engineering of modern materials for information technology, renewable energy and sensing** | | | | | | | | | | | | |
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|  | Qualification | | | | |  |  |  | **Master** | | | | | | | | | | | | |
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|  | Form of education | | | | |  |  |  | **Full-time** | | | | | | | | | |  |  |  |
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|  | Total labor intensity | | | |  |  |  |  | **5 credits** | | | | | | | | | |  |  |  |
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| **Distribution of discipline hours and forms of intermediate certification by semesters** | | | | | | | | | | | | | | | | | | | | | |
| Semester | | Credits | Distribution of hours | | | | | | | | | | | | | | | Forms of intermediate attestation | | |  |
| Total | Lectures | | | | Laboratory work | | | Practical classes | Independent work of students | | Contact work during practice and (or) certification | | | Control of training |  |
| 1 | | 5 | 180 | 32 | | | | 0 | | | 32 | 80 | | 2,35 | | | 33,65 | Exam | | |  |
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| The program was made by: |  |  |  |  |
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| *Doctor of Science in Physico-mathematical Sciences, Professor, A. Yurasov \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_* | | | | |
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| Working program of the discipline | | |  |  |
| **Physics of the solid state** | | | | |
|  |  |  |  |  |
| it is developed in accordance with FSES HE: | | |  |  |
| Federal State Educational Standard of Higher Education - Magistracy in the Direction of training 11.04.04 Electronics and nanoelectronics (order of the Ministry of Science and Higher Education of the Russian Federation from 22.09.2017. № 959) | | | | |
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| it is based on the curriculum: | | |  |  |
| Direction of training: 11.04.04 Electronics and nanoelectronics  Profile: «Engineering of modern materials for information technology, renewable energy and sensing» | | | | |
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| The working program was approved at the meeting of the department | | | | |
| **Department of Nanoelectronics** | | | | |
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| Minutes of meeting from 02.03.2021 № 3  Head of the Department A. Sigov \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ | | | | |

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| **Approval of the WPD for execution in the next academic year** | | | | |
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| The working program was revised, discussed and approved for execution in the 2022-2023 academic year at a meeting of the department | | | | |
| **Department of Nanoelectronics** | | | | |
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|  | Minutes of meeting from \_\_ \_\_\_\_\_\_\_\_\_\_ 2022. № \_\_  Head of the Department \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ | | | |
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| **Approval of the WPD for execution in the next academic year** | | | | |
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| The working program was revised, discussed and approved for execution in the 2023-2024 academic year at a meeting of the department | | | | |
| **Department of Nanoelectronics** | | | | |
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|  | Minutes of meeting from \_\_ \_\_\_\_\_\_\_\_\_\_ 2023. № \_\_  Head of the Department \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ | | | |
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| **Approval of the WPD for execution in the next academic year** | | | | |
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| The working program was revised, discussed and approved for execution in the 2024-2025 academic year at a meeting of the department | | | | |
| **Department of Nanoelectronics** | | | | |
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|  | Minutes of meeting from \_\_ \_\_\_\_\_\_\_\_\_\_ 2024. № \_\_  Head of the Department \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ | | | |
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| **Approval of the WPD for execution in the next academic year** | | | | |
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| The working program was revised, discussed and approved for execution in the 2025-2026 academic year at a meeting of the department | | | | |
| **Department of Nanoelectronics** | | | | |
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|  | Minutes of meeting from \_\_ \_\_\_\_\_\_\_\_\_\_ 2025. № \_\_  Head of the Department \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ | | | |
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| **1. OBJECTIVES OF MASTERING THE DISCIPLINE (MODULE)** | | | | | |
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| The discipline «Physics of the solid state» aims to contribute to the formation of students’ competencies, provided by this work program in accordance with the requirements of FSES HE in the direction of training 11.04.04 Electronics and nanoelectronics, taking into account the specifics of the profile – «Engineering of modern materials for information technology, renewable energy and sensing». | | | | | |
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| **2. PLACE OF DISCIPLINE (MODULE) IN THE STRUCTURE OF THE EDUCATIONAL PROGRAM** | | | | | |
|  | Direction of training: |  | 11.04.04 Electronics and nanoelectronics | | |
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|  | Profile: |  | Engineering of modern materials for information technology, renewable energy and sensing | | |
|  |  |  |
|  | Block: |  | Disciplines (modules) | | |
|  |  |  |
|  | Part: |  | Mandatory part | | |
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|  | Total labor intensity: |  | 5 credits (180 academic hours). | | |
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| **3. THE STUDENT’S COMPETENCIES FORMED AS A RESULT OF MASTERING THE DISCIPLINE (MODULE)** | | | | | |
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| As a result of mastering the practice, the student must master the following competencies: | | | | | |
| **GPC-1** - Capable to present a modern scientific picture of the world, identify the natural science essence of problems, determine ways to solve them and evaluate the effectiveness of the choice made | | | | | |
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| **PLANNED RESULTS OF TRAINING IN THE DISCIPLINE (MODULE), CHARACTERIZING THE FORMATION OF COMPETENCIES** | | | | | |
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| **GPC-1 : Capable to present a modern scientific picture of the world, identify the natural science essence of problems, determine ways to solve them and evaluate the effectiveness of the choice made** | | | | | |
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| **GPC-1.1: Reveals the natural science essence of the problem in the field of electronics** | | | | | |
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| **To know:** | | | | | |
| - basic laws and principles of solid state physics | | | | | |
| **Be able to:** | | | | | |
| - solve problems in solid state physics | | | | | |
| **Possess:** | | | | | |
| - skills of applying general approaches of solid state physics | | | | | |
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| **GPC-1.2: Determines the solutions and evaluates the effectiveness of the choice made when solving a problem in the field of electronics** | | | | | |
| **To know:** | | | | | |
| - fundamental laws of nature and basic physical and mathematical laws for evaluating the effectiveness of choice in the field of micro and nanotechnology, nanoelectronics using the apparatus of solid state physics | | | | | |
| **Be able to:** | | | | | |
| - apply physical and mathematical methods to solve theoretical and applied problems in the field of micro and nanotechnology, nanoelectronics using the apparatus of solid state physics | | | | | |
| **Possess:** | | | | | |

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| - skills of using knowledge of physics and mathematics in solving practical problems in the field of micro and nanotechnology, nanoelectronics with the use of solid state physics apparatus | | | | | | |
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| **AS A RESULT OF STUDYING THE DISCIPLINE (MODULE), THE STUDENT MUST** | | | | | | |
|  |  |  |  |  |  |  |
| **To know:** | | | | | | |
| - fundamental laws of nature and basic physical and mathematical laws for evaluating the effectiveness of choice in the field of micro and nanotechnology, nanoelectronics using the apparatus of solid state physics | | | | | | |
| - basic laws and principles of solid state physics | | | | | | |
| **Be able to:** | | | | | | |
| - apply physical and mathematical methods to solve theoretical and applied problems in the field of micro and nanotechnology, nanoelectronics using the apparatus of solid state physics | | | | | | |
| - solve problems in solid state physics | | | | | | |
| **Possess:** | | | | | | |
| - skills of using knowledge of physics and mathematics in solving practical problems in the field of micro and nanotechnology, nanoelectronics with the use of solid state physics apparatus | | | | | | |
| - skills of applying general approaches of solid state physics | | | | | | |
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| **4. STRUCTURE AND CONTENT OF THE DISCIPLINE (MODULE)** | | | | | | |
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| During the training sessions, the organization ensures the development of students’ teamwork skills, interpersonal communication, decision-making and leadership qualities. | | | | | | |
| **Code** | **Name of sections and topics /type of classes/** | | **Semester** | **Academic Hours** | **Competencies** | |
| **1. Basic laws and principles of solid state physics** | | | | | | |
| **1.1** | **Lecture** **1.** **Introduction to Solid State Physics (Lec).** The concept and types of condensed matter. The place of solid state physics in condensed matter physics. Nobel Prizes in Solid State Physics. Research methods. The main approaches in the study of solid state physics: quasiparticles, electronic structure, transfer phenomena. | | 1 | 2 | GPC-1.1, GPC -1.2 | |
| **1.2** | **Performing practical tasks (Pr).** PR 1. The main approaches in the study of solid state physics: quasiparticles, electronic structure, transfer phenomena. | | 1 | 2 | GPC-1.1, GPC -1.2 | |
| **1.3** | **Preparation for classroom classes (IWS).** Control questions | | 1 | 2 | GPC-1.1, GPC -1.2 | |
| **1.4** | **Homework (IWS).** IWS 1. The main approaches in the study of solid state physics: quasiparticles, electronic structure, transfer phenomena. Control questions | | 1 | 3 | GPC-1.1, GPC -1.2 | |

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| **1.5** | **Lecture** **2.** **The quantum basis of solid state physics. (Lec).** The scale of electromagnetic waves. The planetary model of the atom. Rutherford's experience. Quantum mechanical description of atoms. A hydrogen-like atom. Quantum numbers. Periodic table of elements by D.I. Mendeleev. Transition from summation to integration. Quantum description of systems of many particles. The Hamiltonian of a solid. | 1 | 2 | GPC-1.1, GPC -1.2 |
| **1.6** | **Performing practical tasks (Pr).** ПР 2. Transition from summation to integration. | 1 | 2 | GPC-1.1, GPC -1.2 |
| **1.7** | **Preparation for classroom classes (IWS).** Control questions | 1 | 2 | GPC-1.1, GPC -1.2 |
| **1.8** | **Homework (IWS).** IWS 2. Transition from summation to integration. Control questions | 1 | 3 | GPC-1.1, GPC -1.2 |
| **1.9** | **Lecture** **3** **Basic quantities used in solid state physics** **(Lec).** Basic quantities used in solid state physics. The method of dimensions. Tensor. Physical examples. | 1 | 2 | GPC-1.1, GPC -1.2 |
| **1.10** | **Performing practical tasks (Pr).** PR 3. The method of dimensions. | 1 | 2 | GPC-1.1, GPC -1.2 |
| **1.11** | **Preparation for classroom classes (IWS).** Control questions | 1 | 2 | GPC-1.1, GPC -1.2 |
| **1.12** | **Homework (IWS).** IWS 3. PR 3. The method of dimensions. Control questions | 1 | 3 | GPC-1.1, GPC -1.2 |
| **1.13** | **Lecture** **4** **Types of quasiparticles. Their main characteristics.** **(Lec).** Types of quasiparticles. Their main characteristics. Two types of statistics: Bose-Einstein and Fermi-Dirac statistics. Occupation numbers. | 1 | 2 | GPC-1.1, GPC -1.2 |
| **1.14** | **Performing practical tasks (Pr).** PR 4. Two types of statistics: Bose-Einstein and Fermi-Dirac statistics. Occupation numbers. | 1 | 2 | GPC-1.1, GPC -1.2 |
| **1.15** | **Preparation for classroom classes (IWS).** Control questions | 1 | 2 | GPC-1.1, GPC -1.2 |
| **1.16** | **Homework (IWS).** IWS 4. Two types of statistics: Bose-Einstein and Fermi-Dirac statistics. Occupation numbers. Control questions | 1 | 3 | GPC-1.1, GPC -1.2 |

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| **1.17** | **Lecture** **5** **Fermions and bosons (Lec).** Electronic gas. The Pauli principle. Density of electronic states. The equilibrium distribution at T = 0. Energy, momentum and Fermi velocity of electrons. Fermi distribution at finite temperatures. Chemical potential. The heat capacity of a degenerate fermi gas. Bose gas of particles. Bose-Einstein condensation. | 1 | 2 | GPC-1.1, GPC -1.2 |
| **1.18** | **Performing practical tasks (Pr).** PR 5. Solving typical tasks | 1 | 2 | GPC-1.1, GPC -1.2 |
| **1.19** | **Preparation for classroom classes (IWS).** Control questions | 1 | 2 | GPC-1.1, GPC -1.2 |
| **1.20** | **Homework (IWS).** IWS 5. Control questions. Tasks solving. | 1 | 3 | GPC-1.1, GPC -1.2 |
| **1.21** | **Lecture** **6** **Quasi-classical approximation. Quantum effects. (Lec).** The quasi-classical approximation and the quantum limit. Quantum effects. | 1 | 2 | GPC-1.1, GPC -1.2 |
| **1.22** | **Performing practical tasks (Pr).** PR 6. The quasi-classical approximation and the quantum limit. | 1 | 2 | GPC-1.1, GPC -1.2 |
| **1.23** | **Preparation for classroom classes (IWS).** Control questions | 1 | 2 | GPC-1.1, GPC -1.2 |
| **1.24** | **Homework (IWS).** IWS 6. Control questions. Solving typical tasks. | 1 | 3 | GPC-1.1, GPC -1.2 |
| **1.25** | **Lecture** **7** **Second quantization in solid state physics (Lec).** Secondary quantization. Harmonic oscillator. Secondary quantization of bosons and fermions. The ground state of an ideal quantum gas. Photons. | 1 | 2 | GPC-1.1, GPC -1.2 |
| **1.26** | **Performing practical tasks (Pr).** PR 7. Derivation of the formula for the spectral density of the equilibrium radiation. | 1 | 2 | GPC-1.1, GPC -1.2 |
| **1.27** | **Preparation for classroom classes (IWS).** Control questions | 1 | 2 | GPC-1.1, GPC -1.2 |
| **1.28** | **Homework (IWS).** IWS 7. Derivation of the formula for the spectral density of the equilibrium radiation. Control questions | 1 | 3 | GPC-1.1, GPC -1.2 |

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| **1.29** | **Lecture** **8** **Fundamentals of crystal physics (Lec).** Amorphous and crystalline bodies, liquids and liquid crystals. Broadcasts, an elementary cell. Bravais lattice, basis. Crystal systems and types of Bravais lattices. Point and spatial symmetry transformations. Point and spatial symmetry groups of a crystal. A primitive Wigner-Seitz elementary cell. Miller indices for atomic planes and crystallographic directions. Atomic structures of some compounds of NaCl, graphite, diamond, etc. Quasicrystals. Diffraction of X-rays and neutrons on a crystal. Wolfe-Bragg conditions. The form factor of the atom. Structural factor. | 1 | 2 | GPC-1.1, GPC -1.2 |
| **1.30** | **Performing practical tasks (Pr).** PR 8. Crystal systems and types of Bravais lattices. A primitive Wigner-Seitz elementary cell. Miller indices for atomic planes and crystallographic directions. Atomic structures of some compounds of NaCl, graphite, diamond, etc. | 1 | 2 | GPC-1.1, GPC -1.2 |
| **1.31** | **Preparation for classroom classes (IWS).** Control questions | 1 | 2 | GPC-1.1, GPC -1.2 |
| **1.32** | **Homework (IWS).** IWS 8. Crystal systems and types of Bravais lattices. A primitive Wigner-Seitz elementary cell. Miller indices for atomic planes and crystallographic directions. Atomic structures of some compounds of NaCl, graphite, diamond, etc. Control questions | 1 | 3 | GPC-1.1, GPC -1.2 |
| **1.33** | **Lecture** **9** **Methods of structural research. Reciprocal lattice. Defects of the crystal lattice. Fundamentals of elasticity theory** **(Lec).** Methods of structural studies: Laue method, rotating crystal, Debye-Scherer powder method. Reciprocal lattice. Vectors of the reciprocal lattice. Bragg planes. The Brillouin zones. Crystal lattice defects: point, linear, flat, volumetric. Burger’s vector. Strain tensor. Elastic stress tensor. Hooke's law. Elastic properties of crystals. | 1 | 2 | GPC-1.1, GPC -1.2 |
| **1.34** | **Performing practical tasks (Pr).** PR 9. The inverse space. Vectors of the reciprocal lattice. Bragg planes. The Brillouin zones. | 1 | 2 | GPC-1.1, GPC -1.2 |
| **1.35** | **Preparation for classroom classes (IWS).** Control questions | 1 | 2 | GPC-1.1, GPC -1.2 |

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| **1.36** | **Homework (IWS).** IWS 9. PR 9. The inverse space. Vectors of the reciprocal lattice. Bragg planes. The Brillouin zones. Control questions | 1 | 3 | GPC-1.1, GPC -1.2 |
| **1.37** | **Lecture** **10** **Phonons** **(Lec).** Laws of dispersion. Acoustic and optical vibrations. Quantization of crystal lattice vibrations. The concept of quasiparticles. Phonons. The energy and quasi-pulse of the phonon. Phonon birth and destruction operators. The particle number operator. Spectral density of phonon states. Phonon spectra. | 1 | 2 | GPC-1.1, GPC -1.2 |
| **1.38** | **Performing practical tasks (Pr).** PR 10. Phonons. The energy and quasi-pulse of the phonon. Phonon birth and destruction operators. The particle number operator. Spectral density of phonon states. Phonon spectra. | 1 | 2 | GPC-1.1, GPC -1.2 |
| **1.39** | **Preparation for classroom classes (IWS).** Control questions | 1 | 2 | GPC-1.1, GPC -1.2 |
| **1.40** | **Homework (IWS).** IWS 10. Phonons. The energy and quasi-pulse of the phonon. Phonon birth and destruction operators. The particle number operator. Spectral density of phonon states. Phonon spectra. Control questions | 1 | 3 | GPC-1.1, GPC -1.2 |
| **1.41** | **Lecture** **11** **The heat capacity of the crystal lattice. Contribution of electronic heat capacity.** **(Lec).** The heat capacity of the crystal lattice. The law of Dulong-Petit. Einstein and Debye models. The contribution of the electronic heat capacity. | 1 | 2 | GPC-1.1, GPC -1.2 |
| **1.42** | **Performing practical tasks (Pr).** PR 11. The heat capacity of the crystal lattice. The law of Dulong-Petit. Einstein and Debye models. The contribution of the electronic heat capacity. | 1 | 2 | GPC-1.1, GPC -1.2 |
| **1.43** | **Preparation for classroom classes (IWS).** Control questions | 1 | 2 | GPC-1.1, GPC -1.2 |
| **1.44** | **Homework (IWS).** IWS 11. The heat capacity of the crystal lattice. The law of Dulong-Petit. Einstein and Debye models. The contribution of the electronic heat capacity. Control questions | 1 | 3 | GPC-1.1, GPC -1.2 |
| **1.45** | **Lecture** **12** **Electrical properties (Lec).** Conductivity and resistance. Conductors, semiconductors, dielectrics. Resistance of metals. The Matthiessen rule. Dimensional effect of the resistance of alloys. The Nordheim rule. Muiji correlation. The Condo effect. Dielectric constant. The Drude-Lorentz model. | 1 | 2 | GPC-1.1, GPC -1.2 |
| **1.46** | **Performing practical tasks (Pr).** PR 12. Dielectric constant. The Drude-Lorentz model. | 1 | 2 | GPC-1.1, GPC -1.2 |

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| **1.47** | **Preparation for classroom classes (IWS).** Control questions | 1 | 2 | GPC-1.1, GPC -1.2 |
| **1.48** | **Homework (IWS).** IWS 12. Dielectric constant. The Drude-Lorentz model. Control questions | 1 | 3 | GPC-1.1, GPC -1.2 |
| **1.49** | **Lecture** **13** **Magnetic properties of solids (Lec).** Types of magnetic ordering. Ferromagnetism. Magnetic permeability and susceptibility. | 1 | 2 | GPC-1.1, GPC -1.2 |
| **1.50** | **Performing practical tasks (Pr).** PR 13. Types of magnetic ordering. Ferromagnetism. Magnetic permeability and susceptibility. | 1 | 2 | GPC-1.1, GPC -1.2 |
| **1.51** | **Preparation for classroom classes (IWS).** Control questions | 1 | 2 | GPC-1.1, GPC -1.2 |
| **1.52** | **Homework (IWS).** IWS 13. Types of magnetic ordering. Ferromagnetism. Magnetic permeability and susceptibility. Control questions | 1 | 3 | GPC-1.1, GPC -1.2 |
| **1.53** | **Lecture** **14** **Kinetic phenomena (Lec).** Kinetic phenomena. Their classification. Magnetoresistance. GMR, TMR, CMR, GMI. The Hall effect. | 1 | 2 | GPC-1.1, GPC -1.2 |
| **1.54** | **Performing practical tasks (Pr).** PR 14. Magnetoresistance. GMR, TMR, CMR, GMI. The Hall effect. | 1 | 2 | GPC-1.1, GPC -1.2 |
| **1.55** | **Preparation for classroom classes (IWS).** Control questions | 1 | 2 | GPC-1.1, GPC -1.2 |
| **1.56** | **Homework (IWS).** IWS 14. Magnetoresistance. GMR, TMR, CMR, GMI. The Hall effect. Control questions | 1 | 3 | GPC-1.1, GPC -1.2 |
| **1.57** | **Lecture** **15** **Optical and magneto-optical methods for the study of condensed matter.** **(Lec).** Optical and magneto-optical methods for the study of condensed media. Magneto-optical effects. | 1 | 2 | GPC-1.1, GPC -1.2 |
| **1.58** | **Performing practical tasks (Pr).** PR 15. Optical and magneto-optical methods for the study of condensed media. Magneto-optical effects. | 1 | 2 | GPC-1.1, GPC -1.2 |
| **1.59** | **Preparation for classroom classes (IWS).** Control questions | 1 | 2 | GPC-1.1, GPC -1.2 |
| **1.60** | **Homework (IWS).** IWS 15. Optical and magneto-optical methods for the study of condensed media. Magneto-optical effects. Control questions | 1 | 3 | GPC-1.1, GPC -1.2 |

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| **1.61** | **Lecture** **16** **Fundamentals of Nanostructure Physics (Lec).** Nanostructures. Dimensional effect. Optical and magneto-optical effects in nanostructures. Nanocomposites. Theory of effective environment. Magnetorefractive effect as a non-contact method of measuring magnetoresistance. | | 1 | 2 | GPC-1.1, GPC -1.2 | |
| **1.62** | **Performing practical tasks (Pr).** PR 16. Nanostructures. Dimensional effect. Optical and magneto-optical effects in nanostructures. Nanocomposites. Theory of effective environment. Magnetorefractive effect as a non-contact method of measuring magnetoresistance. | | 1 | 2 | GPC-1.1, GPC -1.2 | |
| **1.63** | **Preparation for classroom classes (IWS).** Control questions | | 1 | 2 | GPC-1.2 | |
| **1.64** | **Homework (IWS).** IWS 16. Nanostructures. Dimensional effect. Optical and magneto-optical effects in nanostructures. Nanocomposites. Theory of effective environment. Magnetorefractive effect as a non-contact method of measuring magnetoresistance. Control questions | | 1 | 3 | GPC-1.2 | |
| **2. Intermediate certification (exam)** | | | | | | |
| **2.1** | **Preparation for the intermediate certification (Exam).** | | 1 | 33,65 | GPC-1.1, GPC -1.2 | |
| **2.2** | **Contact work with the teacher during the intermediate certification (CWC).** | | 1 | 2,35 | GPC-1.1, GPC -1.2 | |
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| **5. EVALUATION MATERIALS** | | | | | | |
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| **5.1. List of competencies** | | | | | | |
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| List of competencies, the development of which the study of the discipline is aimed at «Physics of the solid state», with an indication of the results of their formation in the process of mastering the educational program, presented in paragraph 3 of this work program | | | | | | |
| **5.2. Typical control questions and tasks** | | | | | | |
| 1. Basic approaches in the study of solid state physics.  2. Types of quasiparticles. Their main characteristics.  3. Electronic gas.  4. The approximation of almost free electrons. The approximation of a strong bond.  5. Fundamentals of crystal optics.  6. Quantization of crystal lattice vibrations.  7. Types of magnetic ordering.  8. Magnetic permeability and susceptibility. The theory of the mean field.  9. Transfer phenomena. Their classification.  10. Electrical conductivity of metals. Drude's theory. Resistance of metals. Resistance of alloys.  11. Semiconductors.  12. Dielectrics, their types.  13. The phenomenon of superconductivity.  14. Magneto-optical effects. Their use in condensed matter studies.  15. Composites. The role of dimensional effects. Theory of effective environment. | | | | | | |
| **5.3. Fund of evaluation Materials** | | | | | | |

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| A complete list of evaluation materials is provided in the Appendix 1. | | | | | |
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| **6. MATERIAL, TECHNICAL, EDUCATIONAL AND METHODOLOGICAL SUPPORT OF THE DISCIPLINE (MODULE)** | | | | | |
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| **6.1. MATERIAL AND TECHNICAL SUPPORT OF THE DISCIPLINE (МОДУЛЯ)** | | | | | |
| **Name of premises** | | | | **List of main equipment** | |
| Classroom for lectures and seminars, group and individual consultations, ongoing monitoring and intermediate certification | | | | Multimedia equipment, specialized furniture, sets of demonstration equipment and educational and visual aids that provide thematic illustrations. | |
| A room for independent work of students | | | | Computer equipment with the ability to connect to the Internet and provide access to the electronic information and educational environment of the organization. | |
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| **6.2. LIST OF SOFTWARE** | | | | | |
| 1. |  | Microsoft Windows. Contract No. 32009183466 from 02.07.2021. | | | |
| 2. |  | Microsoft Office. Contract No. 32009183466 from 02.07.2021. | | | |
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| **6.3. RECOMMENDED LITERATURE** | | | | | |
| **6.3.1. Basic literature** | | | | | |
| 1. |  | Morozov V. G. Termodinamika i statisticheskaya fizika:uchebnoe posobie. - M.: MIREA, 2018. - 244 s. | | | |
| 2. |  | Yurasov A.Yu. Magnitoopticheskie effekty i magnitorefraktivnyj effekt v nanokompozitah:uchebnoe posobie. - M.: MIREA, 2016. - 56 s. | | | |
| 3. |  | Morozov A. I., Sigov A. S. Frustrirovannye magnitnye nanostruktury:. - M.: FIZMATLIT, 2016. - 140 s. | | | |
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| **6.3.2. Additional literature** | | | | | |
| 1. |  | Irodov I. E. Fizika makrosistem. Osnovnye zakony [Electronic resource]:. - , 2001. - 196 s. – Access mode: http://library.mirea.ru/secret/mm\_06163.djvu | | | |
| 2. |  | Morozov A. I. Teoriya uprugosti [Electronic resource]:uchebnoe posobie. - M.: MGTU MIREA, 2010. - – Access mode: http://library.mirea.ru/secret/e\_949.iso | | | |
| 3. |  | Landau L. D., Lifshic E. M. Teoreticheskaya fizika:[v 10 t.]. - M.: FIZMATLIT, 2005. - | | | |
| 4. |  | Morozov A. I. Fizika tverdogo tela. Kristallicheskaya struktura. Fonony:Ucheb. posobie. - M.: MIREA, 2010. - 139 s. | | | |
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| **6.4. RECOMMENDED LIST OF MODERN PROFESSIONAL DATABASES AND INFORMATION REFERENCE SYSTEMS** | | | | | |
| 1. |  | Electronic fund of legal and regulatory technical documentation Tekhnoexpert http://www.docs.cntd.ru | | | |
| 2. |  | Nanometer - Nanotechnology community http://www.nanometer.ru | | | |
| 3. |  | Information portal «Popular nanotechnologies» http://www.popnano.ru | | | |
| 4. |  | Scientific Electronic Library http://www.elibrary.ru | | | |
| 5. |  | Information portal of the International Citation System «Web of Science”  https://www.apps.webofknowledge.com | | | |
| 6. |  | Information portal of the International Citation System Scopus  https://www.scopus.com | | | |

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| 7. |  | Information and reference portal of scientific publications of domestic and foreign authors «Google Academy»  https://www.scholar.google.ru | | |
| 8. |  | Elektronika NTB - scientific and technical journal  http://www.electronics.ru | | |
| 9. |  | National Research Center «Kurchatov Institute»  http://www.kcsni.nrcki.ru | | |
| 10. |  | Database Web of Science  http://www.webofknowledge.com | | |
| 11. |  | Website of the PTI Department of Nanoelectronics https://fks.mirea.ru | | |
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| **6.5. METHODICAL INSTRUCTIONS FOR STUDENTS STUDYING THE DISCIPLINE (MODULE)** | | | | |
| The student’s independent work is aimed at preparing for academic classes and at developing knowledge, skills and abilities provided for in the discipline program.  In accordance with the curriculum, the discipline may include Lectures, practical classes and Laboratory work, as well as the execution and defense of a course project (work). Successful study of the discipline requires attending all types of classes, completing teacher assignments and familiarization with basic and additional literature. Depending on the activities provided for in the curriculum and section 4 of this program, the student chooses methodological guidelines for independent work from the ones listed below.  When preparing for lecture classes, students need to:  before the next lecture, it is necessary to review the summary of the material of the previous Lectures. If you have difficulties in perceiving the material, you should refer to the main literary sources. If it was not possible to understand the material again, then contact the lecturer (according to the schedule of his consultations) or the teacher in practical classes.  Practical classes complete the study of the most important topics of the discipline. They serve to consolidate the studied material, develop the skills and abilities of preparing reports, messages, gaining experience in oral public speeches, conducting discussions, argumentation and defending the propositions put forward, as well as to monitor the degree of readiness of students in the discipline being studied by the teacher.  When preparing for a practical lesson, students have the opportunity to use the advice of a teacher.  When preparing for practical classes, students need to:  bring with you the literature recommended by the teacher for a specific lesson;  before the next practical lesson on the recommended literary sources, work out the theoretical material corresponding to the topic of the lesson;  at the beginning of classes, ask the teacher questions about the material that caused difficulties in understanding and mastering it when solving tasks set for independent solution;  during the seminar, give specific, clear answers to the substance of the questions;  at the training session, bring each task to the final solution, demonstrate an understanding of the calculations (analyses, situations), in case of difficulties, contact the teacher.  Students who have missed classes (regardless of the reasons), who do not have a written solution to problems or are not prepared for this practical lesson, are recommended to come to the teacher’s consultation no later than 2 weeks and report on the topic studied in the lesson.  The methodological guidelines necessary for studying and passing the discipline are given as part of the educational program. | | | | |
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| **6.6. METHODOLOGICAL RECOMMENDATIONS FOR THE TRAINING OF PERSONS WITH LIMITED HEALTH OPPORTUNITIES AND THE DISABLED** | | | | |

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| The development of the discipline by students with disabilities can be organized both jointly with other students and in separate groups. Special conditions are assumed for students with disabilities to receive education.  The teaching staff gets acquainted with the psychological and physiological characteristics of students with disabilities and persons with disabilities, individual rehabilitation programs for the disabled (if available). If necessary, additional teaching support is provided by tutors, psychologists, social workers, trained assistants.  In accordance with the methodological recommendations of the Ministry of Education and Science of the Russian Federation (approved April 8, 2014 N AK-44/05vn), the course is supposed to use socially active and reflective teaching methods, technologies of socio-cultural rehabilitation in order to assist in establishing full-fledged interpersonal relationships with other students, creating a comfortable psychological climate in the student group. Selection and development of educational materials are made taking into account the provision of material in various forms: auditory, visual, using special technical means and information systems.  Mediamaterials should also be used and adapted taking into account the individual characteristics of the training of persons with disabilities.  The development of the discipline by persons with disabilities is carried out using general and special purpose teaching tools (personal and collective use). Material and technical support provides for the adaptation of classrooms to the needs of persons with disabilities.  The form of certification for students with disabilities is established taking into account individual psychophysical characteristics. For students with HIA, an accessible form of assignment of assessment tools is provided, namely:  - in printed or electronic form (for persons with disorders of the musculoskeletal system);  - in printed or electronic form with enlarged font and contrast (for persons with hearing, speech, vision impairments);  - reading the task aloud by the assistant (for visually impaired persons).  Students with disabilities have increased time to prepare answers to control questions. For such students, an accessible form of providing answers to tasks is provided, namely:  - written on paper or a set of answers on a computer (for persons with hearing and speech impairments);  - choosing an answer from possible options using the services of an assistant (for people with musculoskeletal disorders);  - oral interview (for persons with visual impairments, musculoskeletal system).  If necessary, for students with disabilities, the procedure for evaluating learning outcomes can be carried out in several stages. |

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| Federal State Budget Educational Institution of Higher Education  «MIREA – Russian Technological University» | | | | | | | | | | | | | | | | | | | | | |
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| Working program of the discipline (module) | | | | | | | | | | | | | | | | | | | | | |
| **Chemistry for material engineering** | | | | | | | | | | | | | | | | | | | | | |
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|  | Department leading the training | | | | | |  |  | **Department of Nanoelectronics** | | | | | | | | | | | | |
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|  | Direction of training | | | | | | |  | **11.04.04 Electronics and nanoelectronics** | | | | | | | | | | | | |
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|  | Profile | | | | | | |  | **Engineering of modern materials for information technology, renewable energy and sensing** | | | | | | | | | | | | |
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|  | Qualification | | | | |  |  |  | **Master** | | | | | | | | | | | | |
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|  | Form of education | | | | |  |  |  | **Full-time** | | | | | | | | | |  |  |  |
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|  | Total labor intensity | | | |  |  |  |  | **5 credits** | | | | | | | | | |  |  |  |
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| **Distribution of discipline hours and forms of intermediate certification by semesters** | | | | | | | | | | | | | | | | | | | | | |
| Semester | | Credits | Distribution of hours | | | | | | | | | | | | | | | Forms of intermediate attestation | | |  |
| Total | Lectures | | | | Laboratory work | | | Practical classes | Independent work of students | | Contact work during practice and (or) certification | | | Control of training |  |
| 1 | | 5 | 180 | 16 | | | | 16 | | | 32 | 80 | | 2,35 | | | 33,65 | Exam | | |  |
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| The program was made by: |  |  |  |  |
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| *Doctor of Science in Technical Sciences, Professor, A. Bush \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_* | | | | |
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| Working program of the discipline | | |  |  |
| **Chemistry for material engineering** | | | | |
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| it is developed in accordance with FSES HE: | | |  |  |
| Federal State Educational Standard of Higher Education - Magistracy in the Direction of training 11.04.04 Electronics and nanoelectronics (order of the Ministry of Science and Higher Education of the Russian Federation from 22.09.2017. № 959) | | | | |
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| it is based on the curriculum: | | |  |  |
| Direction of training: 11.04.04 Electronics and nanoelectronics  Profile: «Engineering of modern materials for information technology, renewable energy and sensing» | | | | |
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| The working program was approved at the meeting of the department | | | | |
| **Department of Nanoelectronics** | | | | |
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| Minutes of meeting from 02.03.2021 № 3  Head of the Department A. Sigov \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ | | | | |

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| **Approval of the WPD for execution in the next academic year** | | | | |
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| The working program was revised, discussed and approved for execution in the 2022-2023 academic year at a meeting of the department | | | | |
| **Department of Nanoelectronics** | | | | |
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|  | Minutes of meeting from \_\_ \_\_\_\_\_\_\_\_\_\_ 2022. № \_\_  Head of the Department \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ | | | |
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| **Approval of the WPD for execution in the next academic year** | | | | |
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| The working program was revised, discussed and approved for execution in the 2023-2024 academic year at a meeting of the department | | | | |
| **Department of Nanoelectronics** | | | | |
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|  | Minutes of meeting from \_\_ \_\_\_\_\_\_\_\_\_\_ 2023. № \_\_  Head of the Department \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ | | | |
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| **Approval of the WPD for execution in the next academic year** | | | | |
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| The working program was revised, discussed and approved for execution in the 2024-2025 academic year at a meeting of the department | | | | |
| **Department of Nanoelectronics** | | | | |
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|  | Minutes of meeting from \_\_ \_\_\_\_\_\_\_\_\_\_ 2024. № \_\_  Head of the Department \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ | | | |
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| **Approval of the WPD for execution in the next academic year** | | | | |
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| The working program was revised, discussed and approved for execution in the 2025-2026 academic year at a meeting of the department | | | | |
| **Department of Nanoelectronics** | | | | |
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|  | Minutes of meeting from \_\_ \_\_\_\_\_\_\_\_\_\_ 2025. № \_\_  Head of the Department \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ | | | |
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| **1. OBJECTIVES OF MASTERING THE DISCIPLINE (MODULE)** | | | | | |
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| The discipline «Chemistry for material engineering» aims to contribute to the formation of students’ competencies, provided by this work program in accordance with the requirements of FSES HE in the direction of training 11.04.04 Electronics and nanoelectronics, taking into account the specifics of the profile – «Engineering of modern materials for information technology, renewable energy and sensing». | | | | | |
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| **2. PLACE OF DISCIPLINE (MODULE) IN THE STRUCTURE OF THE EDUCATIONAL PROGRAM** | | | | | |
|  | Direction of training: |  | 11.04.04 Electronics and nanoelectronics | | |
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|  | Profile: |  | Engineering of modern materials for information technology, renewable energy and sensing | | |
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|  | Block: |  | Disciplines (modules) | | |
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|  | Part: |  | Mandatory part | | |
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|  | Total labor intensity: |  | 5 credits (180 academic hours). | | |
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| **3. THE STUDENT’S COMPETENCIES FORMED AS A RESULT OF MASTERING THE DISCIPLINE (MODULE)** | | | | | |
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| As a result of mastering the practice, the student must master the following competencies: | | | | | |
| **GPC-1** - Capable to present a modern scientific picture of the world, identify the natural science essence of problems, determine ways to solve them and evaluate the effectiveness of the choice made | | | | | |
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| **PLANNED RESULTS OF TRAINING IN THE DISCIPLINE (MODULE), CHARACTERIZING THE FORMATION OF COMPETENCIES** | | | | | |
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| **GPC-1 : Capable to present a modern scientific picture of the world, identify the natural science essence of problems, determine ways to solve them and evaluate the effectiveness of the choice made** | | | | | |
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| **GPC-1.1: Reveals the natural science essence of the problem in the field of electronics** | | | | | |
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| **To know:** | | | | | |
| - the main methods of studying and describing the structure of microelectronics materials: their macrostructures and microstructures, the internal structure of matter (the structure of atoms, ions, molecules and crystals), features of the structure and properties of crystals of the most important structural types. | | | | | |
| **Be able to:** | | | | | |
| - interpret data on the structure of atoms, ions and molecules, atomic crystal structure, use these data to determine the main features of the properties of atoms, ions, molecules, crystals | | | | | |
| **Possess:** | | | | | |
| - skills of defining, describing and interpreting the main features of the structure and properties of atoms, ions, molecules, crystals | | | | | |
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| **GPC-1.2: Determines the solutions and evaluates the effectiveness of the choice made when solving a problem in the field of electronics** | | | | | |
| **To know:** | | | | | |
| - The main results of the physicochemical analysis of chemical processes in heterogeneous systems, phase diagrams of mono-, two- and three-component systems, surface | | | | | |

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| phenomena; basic concepts and concepts of chemical kinetics and electrochemical processes | | | | | | |
| **Be able to:** | | | | | | |
| - use the results of physicochemical analysis to determine the optimal methods and modes of synthesis of microelectronics materials, to predict their properties | | | | | | |
| **Possess:** | | | | | | |
| - skills of using the results of physicochemical analysis to determine methods and modes of synthesis of microelectronics materials, to predict their properties | | | | | | |
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| **AS A RESULT OF STUDYING THE DISCIPLINE (MODULE), THE STUDENT MUST** | | | | | | |
|  |  |  |  |  |  |  |
| **To know:** | | | | | | |
| - The main results of the physicochemical analysis of chemical processes in heterogeneous systems, phase diagrams of mono-, two- and three-component systems, surface phenomena; basic concepts and concepts of chemical kinetics and electrochemical processes | | | | | | |
| - the main methods of studying and describing the structure of microelectronics materials: their macrostructures and microstructures, the internal structure of matter (the structure of atoms, ions, molecules and crystals), features of the structure and properties of crystals of the most important structural types. | | | | | | |
| **Be able to:** | | | | | | |
| - use the results of physicochemical analysis to determine the optimal methods and modes of synthesis of microelectronics materials, to predict their properties | | | | | | |
| - interpret data on the structure of atoms, ions and molecules, atomic crystal structure, use these data to determine the main features of the properties of atoms, ions, molecules, crystals | | | | | | |
| **Possess:** | | | | | | |
| - skills of using the results of physicochemical analysis to determine methods and modes of synthesis of microelectronics materials, to predict their properties | | | | | | |
| - skills of defining, describing and interpreting the main features of the structure and properties of atoms, ions, molecules, crystals | | | | | | |
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| **4. STRUCTURE AND CONTENT OF THE DISCIPLINE (MODULE)** | | | | | | |
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| During the training sessions, the organization ensures the development of students’ teamwork skills, interpersonal communication, decision-making and leadership qualities. | | | | | | |
| **Code** | **Name of sections and topics /type of classes/** | | **Semester** | **Academic Hours** | **Competencies** | |
| **1. The doctrine of the structure of matter: macrostructure and microstructure of materials, internal structure of matter (structure and properties of atoms, ions, molecules, radicals, nature of chemical bond, description of atomic crystal structure)** | | | | | | |

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| **1.1** | **Lecture** **1.** **Subject, main sections and methods of physical chemistry. The structure of matter: quantum mechanical description of the structure of the atom (Lec).** Subject, research methods and main sections of physical chemistry. The main physico-chemical regularities are the theoretical basis of technological processes of solid-state electronics. Quantum mechanical description of atomic systems. The Schrodinger equation. Atomic orbitals of hydrogen-like atoms. The spin of the electron. Quantum numbers – n, l, m, s, j. Spatial distribution of electron density. The Hamiltonian of a free multielectron atom. Approaches to solving the Schrodinger equation for a multi-electron atom. Atomic orbitals and quantum numbers of multielectronic atoms. The Pauli prohibition principle. Electronic configurations and terms. Hund rules. Electronic layers and shells. A sequence of energy levels. Periodic law of chemical elements by D.I. Mendeleev. s-, p- and transition elements. Orbital and spin magnetism of the electron shell. Diamagnets and paramagnets. Magnetic properties of transition element ions. | 1 | 2 | GPC-1.1 |
| **1.2** | **Oral interview (Pr).** Control questions for the lecture 1 | 1 | 2 | GPC-1.1 |
| **1.3** | **Conducting seminars** **(Pr).** Questions about the lecture 1 | 1 | 2 | GPC-1.1 |
| **1.4** | **Preparation for classroom classes (IWS).** Control questions for the lecture1 | 1 | 4 | GPC-1.1 |
| **1.5** | **Homework (IWS).** IWS 1. Preparation of a review on the topic "The structure of matter: a quantum mechanical description of the structure of the atom". | 1 | 6 | GPC-1.1 |

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| **1.6** | **Lecture** **2.** **Structure of matter: chemical bond and structure of molecules.** **(Lec).** Definition and basic parameters of a chemical bond. The structure of molecules. Types of chemical bonds. Ionization energy, electron affinity and electronegativity. Polarity and polarizability of the connection. Quantum mechanical model of covalent bond by the valence bond method. Heitler and London's solution of the Schrodinger equation for the H2 molecule. The exchange mechanism of covalent bond formation. Multiplicity of communication; sigma-, pi- and delta communications. Theory of hybridization. Spatial configuration of molecules and complexes. The influence of an unshared electron pair of a central atom on the structure of molecules. The provisions underlying the valence bond method. Theory of molecular orbitals. The Linear combination of atomic orbitals (LCAO) method. Binding, non-binding and loosening molecular orbitals (MO). Energy diagrams of MO. MO designations. The order of communication. MO in diatomic, triatomic and pentatomic molecules. | 1 | 2 | GPC-1.1 |
| **1.7** | **Oral interview (Pr).** Control questions for the lecture 2 | 1 | 2 | GPC-1.1 |
| **1.8** | **Conducting seminars** **(Pr).** Questions about the lecture 2 | 1 | 2 | GPC-1.1 |
| **1.9** | **Laboratory work 1** **(LW).** Methods of X-ray phase analysis. | 1 | 4 | GPC-1.1, GPC -1.2 |
| **1.10** | **Preparation for classroom classes (IWS).** Control questions for the lecture2 | 1 | 4 | GPC-1.1 |

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| **1.11** | **Lecture** **3.** **Structure of the substance: description of the crystal structure.** **(Lec).** Levels of structure: macro-, micro-, nano-, atomic crystal structure. Definitions, examples. Crystal definition: non-periodic structures (quasicrystals, modulated and composite structures), periodic structures. Crystals with periodic structures. Concepts: crystal lattice, node, unit cell. Unambiguous choice of an elementary cell, Bravais rules. 14 Bravais lattices. Crystal system, crystallographic systems. Closed and open symmetry elements. Point and spatial symmetry groups, their symbolism. Polar, non-centrosymmetric and centrosymmetric point groups. Time inversion operation (antisymmetry). Magnetic symmetry groups. Atomic crystal structure, isostructure, isotype, coordination numbers and coordination polyhedra. Examples of crystal structures (perovskite, layered perovskites, spinels, cuprates exhibiting high-temperature superconductivity). Physicochemical fundamentals of controlling the type and concentration of point defects in crystalline phases of variable composition. | 1 | 2 | GPC-1.1 |
| **1.12** | **Homework (IWS).** IWS 2. Preparation of a review on the topic "The structure of matter: chemical bonding and the structure of molecules". | 1 | 6 | GPC-1.1 |
| **1.13** | **Oral interview (Pr).** ПР 3. Control questions for the lecture3 | 1 | 2 | GPC-1.1 |
| **1.14** | **Conducting seminars** **(Pr).** Questions about the lecture 3 | 1 | 2 | GPC-1.1 |
| **1.15** | **Preparation for classroom classes (IWS).** Control questions for the lecture3 | 1 | 4 | GPC-1.1 |
| **1.16** | **Homework (IWS).** IWS 3. Preparation of a review on the topic "The structure of matter: a description of the structure of crystals". | 1 | 6 | GPC-1.1 |

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| **1.17** | **Lecture** **4.** **The doctrine of solutions.** **(Lec).** Solutions: definition, concepts and classification. Ideal, regular, real solutions. Various ways of expressing the composition of solutions: mass, molar fraction and volume fraction of the components of the solution. Saturated vapor pressure of solutions. Raoul's law and its thermodynamic justification. Absolutely perfect solutions. Consequences of Raoul's law. Lowering the crystallization temperature of solutions (cryoscopy). An increase in the boiling point of solutions of non-volatile substances (ebullioscopy). Osmotic pressure of solutions. The Van't-Hoff equation for the osmotic pressure of ideal and extremely dilute solutions. Absorption. Gas pressure over an imperfect solution. Henry's law. The law of distribution of the dissolved substance by phases in a heterogeneous system. Extraction. Purification of metals from impurities by zone melting. Thermodynamics of imperfect solutions. Accounting for deviations in the behavior of real solutions from ideal solutions by replacing the concentration of the solution with its activity. Selection of the standard state of the solution.  Types of solid solutions. Factors affecting the formation of solid solutions. Morphotropic transitions. | 1 | 2 | GPC-1.1 |
| **1.18** | **Oral interview (Pr).** ПР 4. Control questions for the lecture4 | 1 | 2 | GPC-1.1 |
| **1.19** | **Conducting seminars** **(Pr).** Questions about the lecture 4 | 1 | 2 | GPC-1.1 |
| **1.20** | **Laboratory work 2.** **(LW).** Derivatographic analysis of the decomposition process MCO3, M = Ca, Sr, Ba. | 1 | 4 | GPC-1.1, GPC -1.2 |
| **1.21** | **Preparation for classroom classes (IWS).** Control questions for the lecture4 | 1 | 4 | GPC-1.1 |
| **1.22** | **Homework (IWS).** IWS 4. Preparation of a review on the topic "The Doctrine of solutions". | 1 | 6 | GPC-1.1 |

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| **2. Physicochemical fundamentals of synthesis and analysis of microelectronics materials (chemical processes in heterogeneous systems, phase diagrams of mono-, two- and three-component systems, fundamentals of chemical kinetics, basic concepts of electrochemical processes, surface phenomena)** | | | | |
| **2.1** | **Lecture** **5.** **Chemical processes in heterogeneous systems. State diagrams (phase diagrams) composition-property. (Lec).** Homogeneous and heterogeneous systems. Phase, independent components, degrees of freedom of the system. General equilibrium conditions in heterogeneous systems. Gibbs phase rule. Single-component systems. Equilibrium relations at phase transitions. The Clapeyron-Clausius equation. State diagrams (phase diagrams) composition-property. Phase diagrams are the physicochemical bases of the synthesis of substances. Types of state diagrams of two-component systems. Melting diagrams of systems whose components form: eutectic mixture; solid solutions; congruently and incongruently melting intermediate chemical compounds. Eutectic, peritectic. General characteristics of three-component systems. Properties of the concentration triangle. Phase diagrams of importance in microelectronics. | 1 | 2 | GPC-1.2 |
| **2.2** | **Oral interview (Pr).** ПР 5. Control questions for the lecture5 | 1 | 2 | GPC-1.2 |
| **2.3** | **Conducting seminars** **(Pr).** Questions about the lecture 5 | 1 | 2 | GPC-1.2 |
| **2.4** | **Preparation for classroom classes (IWS).** Control questions for the lecture4 | 1 | 4 | GPC-1.2 |
| **2.5** | **Homework (IWS).** IWS 5. Preparation of a review on the topic "Chemical processes in heterogeneous systems. State diagrams (phase diagrams) composition-property". | 1 | 6 | GPC-1.1, GPC -1.2 |

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| **2.6** | **Lecture** **6.** **Fundamentals of chemical kinetics.** **(Lec).** Kinetics of homogeneous chemical reactions. The speed of the chemical reaction. The basic law of chemical kinetics (the law of acting masses). Guldberg-Waage law. The equilibrium constant of a chemical reaction. The molecularity and order of the chemical reaction. Mono-, bi- and trimolecular reactions. The reasons for the discrepancy between the order of the reaction and its molecularity. Expressions for the reaction rate of the first, second and third orders. The half-life (half-transformation). Methods for determining the order of chemical reactions. The effect of temperature on the rate of chemical reactions. The Van't-Goff rule. The Arrhenius equation. The activation energy of a chemical reaction, its physical meaning. Theory of active collisions. The theory of the transition state (the theory of the active complex). Energy diagrams of the reaction path. The dependence of the reaction rate on the entropy of activation. Complex reactions: reversible, sequential and parallel, stepwise, consequential, conjugate, chain. Features of the kinetics of heterogeneous processes. The order of heterogeneous reactions. Diffusion and chemical limits of the reaction rate. Kinetic and diffusion areas of heterogeneous process control. Homogeneous and heterogeneous catalysis. Catalysts and inhibitors. The order of heterogeneous reactions. Homogeneous and heterogeneous catalysis. Catalysts and inhibitors. | 1 | 2 | GPC-1.2 |
| **2.7** | **Oral interview (Pr).** ПР 6. Control questions for the lecture6 | 1 | 2 | GPC-1.2 |
| **2.8** | **Conducting seminars** **(Pr).** Questions about the lecture 6 | 1 | 2 | GPC-1.2 |
| **2.9** | **Laboratory work 3** **(LW).** Obtaining ceramic samples of ferroelectric phase BaTiO3. | 1 | 4 | GPC-1.1, GPC -1.2 |
| **2.10** | **Preparation for classroom classes (IWS).** Control questions for the lecture6 | 1 | 4 | GPC-1.1 |
| **2.11** | **Homework (IWS).** IWS 6. Preparation of a review on the topic "Fundamentals of chemical kinetics". | 1 | 6 | GPC-1.1 |

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| **2.12** | **Lecture** **7.** **Basic concepts of electrochemical processes.** **(Lec).** The subject of electrochemistry as a science. Solutions of electrolytes. Solid electrolytes. Arrhenius theory of electrolytic dissociation. Strong and weak electrolytes, isotonic coefficient. Ostwald's law of dilution. Causes of electrolytic dissociation. Thermodynamic method for studying the properties of strong electrolytes. Activity, activity coefficient. Specific and equivalent electrical conductivity of electrolytes, their concentration dependence. Electrochemical cell (galvanic cell - GC). Double electric layer, electrolytic elasticity of dissolution. electrode potentials, EMF GC. The Nernst formula for the electrode potential. Standard hydrogen electrode. The hydrogen scale of potentials. Electrochemical voltage range. Examples of galvanic cells. Nonequilibrium electrochemical processes. Electrolysis. Faraday's laws of electrolysis. Electrochemical kinetics and electrode processes. Polarization of the electrodes. Electrode polarization. Electrode overvoltage, its types. The decomposition voltage of the electrolyte. Polarographic analysis. Geyrovsky polarograph. Applications of electrochemical processes. Chemical current sources. Electroplating. Electrochemical separation of metals, their refining. Electrochemical dissolution and passivity of metals. Anodic dissolution of metals and alloys, cathodic deposition of metals. Corrosion and corrosion protection. | 1 | 2 | GPC-1.2 |
| **2.13** | **Oral interview (Pr).** ПР 7. Control questions for the lecture7 | 1 | 2 | GPC-1.2 |
| **2.14** | **Conducting seminars** **(Pr).** Questions about the lecture 7 | 1 | 2 | GPC-1.1 |
| **2.15** | **Preparation for classroom classes (IWS).** Control questions for the lecture7 | 1 | 4 | GPC-1.2 |
| **2.16** | **Homework (IWS).** IWS 7. Preparation of a review on the topic "Basic concepts of electrochemical processes". | 1 | 6 | GPC-1.1 |

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| **2.17** | **Lecture** **8.** **Surface phenomena** **(Lec).** Surface and related objects, the difference of their physical properties from the properties of bulk phases.  Surface energy and its anisotropy. Thermodynamics of the surface. Equilibrium forms of bodies. Surface tension. Pressure above the curved surface of the liquid. The Laplace equation. The dependence of the saturated vapor pressure of the liquid on the curvature of the surface. The Thomson (Kelvin) equation and its consequences. Features of the atomic structure of the surface layer. Relaxation and reconstruction of structure in surface systems. Wetting and spreading of the liquid. Leophilic and leophobic systems. Adhesion, cohesion. The work of cohesion and adhesion, the Dupree equation. Capillary phenomena. The formula of Juren. Porosity. Capillary condensation. Adsorption on surfaces of solid or liquid bodies. Physical and chemical adsorption. Gibbs and Langmuir adsorption isotherm equation. Monomolecular and potential adsorption theories. Influence of surface heterogeneity and crystal energy on adsorption. The equation of polymolecular adsorption. Supramolecular structure of adsorbents. Surfactants (surfactants). The Rebinder effect. The use of adsorbents. Desorption. Thermodesorption spectroscopy. Mechanisms of growth on the surface: Vollmer-Weber embryonic growth, Frank-van der Merwe layered growth, Stransky–Krastanov mixed growth mechanism. Epitaxial films. | 1 | 2 | GPC-1.2 |
| **2.18** | **Oral interview (Pr).** ПР 8. Control questions for the lecture8 | 1 | 2 | GPC-1.2 |
| **2.19** | **Conducting seminars** **(Pr).** Questions about the lecture \* | 1 | 2 | GPC-1.2 |
| **2.20** | **Laboratory work 4** **(LW).** Methods of growing single crystals, obtaining Al2O3 crystals by non-ash zone melting. | 1 | 4 | GPC-1.2, GPC -1.1 |
| **2.21** | **Preparation for classroom classes (IWS).** Control questions for the lecture4 | 1 | 4 | GPC-1.2 |
| **2.22** | **Homework (IWS).** IWS 8. Preparation of a review on the topic "Surface phenomena". | 1 | 6 | GPC-1.1 |
| **3. Intermediate certification (exam)** | | | | |
| **3.1** | **Preparation for the intermediate certification (Exam).** | 1 | 33,65 | GPC-1.1, GPC -1.2 |
| **3.2** | **Contact work with the teacher during the intermediate certification (CWC).** | 1 | 2,35 | GPC-1.1, GPC -1.2 |

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| **5. EVALUATION MATERIALS** | | |
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| **5.1. List of competencies** | | |
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| List of competencies, the development of which the study of the discipline is aimed at «Chemistry for material engineering», with an indication of the results of their formation in the process of mastering the educational program, presented in paragraph 3 of this work program | | |
| **5.2. Typical control questions and tasks** | | |
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| З Write down the Hamiltonian of a free multielectron atom.  The type of wave functions obtained by solving the Schrodinger equation for hydrogen-like atoms.  What determines the quantum numbers - n, l. m, s, j.  Spatial distribution of the electron density of s-, p- and d-electrons.  Approaches to solving the Schrodinger equation for a multi-electron atom.  Atomic orbitals and quantum numbers of multielectronic atoms.  The Pauli prohibition principle. Electronic configurations and terms. Hund rules.  Electronic layers and shells.  A sequence of energy levels. Periodic law of chemical elements by D.I. Mendeleev. s-, p- and transition elements.  The influence of an unshared electron pair of a central atom on the spatial structure of molecules.  The theory of molecular orbitals (MO). The LCAO MO method.  Energy diagrams of MO. Binding, non-binding and loosening MO. MO designations. The order of communication.  Features of single-component systems, equilibrium relations at phase transitions, the Clapeyron-Clausius equation.  State diagrams (phase diagrams) composition-property. Phase diagrams are the physico-chemical bases of the synthesis of substances.  Types of diagrams of states of two-component systems (diagrams of the fusibility of systems whose components form: eutectic mixture; solid solutions; congruently and incongruently melting intermediate chemical compounds).  Give definitions of eutectic, peritectic, give examples of state diagrams containing them.  General characteristics of three-component systems. Properties of the concentration triangle.  Phase diagrams of importance in microelectronics.  To define the surface and related objects, to indicate the difference between their physical properties and the properties of bulk phases.  Surface energy and its anisotropy. Thermodynamics of the surface.  Surface tension. Pressure above the curved surface of the liquid. The Laplace equation.  The dependence of the saturated vapor pressure of the liquid on the curvature of the surface. The Thomson (Kelvin) equation and its consequences.  Features of the atomic structure of the surface layer. Relaxation and reconstruction of structure in surface systems.  Wetting and spreading of the liquid. Leophilic and leophobic systems.  Adhesion, cohesion. The work of cohesion and adhesion, the Dupree equation.  Capillary phenomena. The formula of Juren. Porosity. Capillary condensation.  Adsorption on surfaces of solid or liquid bodies. Physical and chemical adsorption.  Gibbs and Langmuir adsorption isotherm equation.  Influence of surface heterogeneity and crystal energy on adsorption. The equation of polymolecular adsorption.  Supramolecular structure of adsorbents. Surfactants (surfactants). The Rebinder effect. The use of adsorbents.  Desorption. Thermodesorption spectroscopy. | | |

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| Mechanisms of growth on the surface: Vollmer-Weber embryonic growth, Frank-van der Merwe layered growth, Stransky–Krastanov mixed growth mechanism. Epitaxial films. | | | | | |
| **5.3. Fund of evaluation Materials** | | | | | |
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| A complete list of evaluation materials is provided in the Appendix 1. | | | | | |
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| **6. MATERIAL, TECHNICAL, EDUCATIONAL AND METHODOLOGICAL SUPPORT OF THE DISCIPLINE (MODULE)** | | | | | |
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| **6.1. MATERIAL AND TECHNICAL SUPPORT OF THE DISCIPLINE (МОДУЛЯ)** | | | | | |
| **Name of premises** | | | | **List of main equipment** | |
| Classroom for lectures and seminars, group and individual consultations, ongoing monitoring and intermediate certification | | | | Multimedia equipment, specialized furniture, sets of demonstration equipment and educational and visual aids that provide thematic illustrations. | |
| Laboratory of the Research Institute of Solid-State Electronics Materials | | | | Installation for X-ray analysis, Installation for derivatographic analysis, Installation for growing crystals by optical zone melting, Installation for the manufacture of ceramics | |
| A room for independent work of students | | | | Computer equipment with the ability to connect to the Internet and provide access to the electronic information and educational environment of the organization. | |
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| **6.2. LIST OF SOFTWARE** | | | | | |
| 1. |  | Microsoft Windows. Contract No. 32009183466 from 02.07.2021. | | | |
| 2. |  | Microsoft Office. Contract No. 32009183466 from 02.07.2021. | | | |
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| **6.3. RECOMMENDED LITERATURE** | | | | | |
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| **6.3.1. Basic literature** | | | | | |
| 1. |  | Bush A. A. Elektronnaya struktura i svojstva himicheskih elementov [Electronic resource]:. - , 2014. - – Access mode: http://library.mirea.ru/secret/e\_1145.iso | | | |
| 2. |  | Eremin V. V., Kargov S. I., Uspenskaya I. A., Kuz'menko N. E., Lunin V. V. Osnovy fizicheskoj himii. V 2 ch [Electronic resource]:uchebnik. - Moscow: Laboratoriya znanij, 2019. - 625 s. – Access mode: https://e.lanbook.com/book/116100 | | | |
| 3. |  | Bush A. A. Atomno- kristallicheskoe stroenie materialov [Electronic resource]:. - , 2016. - – Access mode: http://library.mirea.ru/secret/ab/1280.iso | | | |
| 4. |  | Bush A. A. Himicheskaya svyaz', stroenie molekul. [Electronic resource]:. - , 2016. - – Access mode: http://library.mirea.ru/secret/e\_1146.iso | | | |
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| **6.3.2. Additional literature** | | | | | |
| 1. |  | Cirel'son V. G. Kvantovaya himiya. Molekuly, molekulyarnye sistemy i tverdye tela [Electronic resource]:uchebnoe posobie dlya vuzov. - Moscow: Laboratoriya znanij, 2017. - 522 s. – Access mode: https://e.lanbook.com/book/94104 | | | |
| 2. |  | Gorshkov V. I., Kuznecov I. A. Osnovy fizicheskoj himii [Electronic resource]:uchebnik. - Moscow: Laboratoriya znanij, 2017. - 410 s. – Access mode: https://e.lanbook.com/book/97412 | | | |

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| 3. |  | Bush A. A. Fiziko-himicheskie osnovy i metody rosta monokristallov, vyrashchivanie kristallov AL2 O3 bestigel'noj zonnoj plavkoj [Electronic resource]:metod. ukaz. dlya stud. dnev. otd.. - M.: MIREA, 2011. - – Access mode: http://library.mirea.ru/secret/e\_528.iso | | |
| 4. |  | Bukanova E. F., Dulina O. A. Kolloidnaya himiya v voprosah i otvetah [Electronic resource]:sbornik zadanij. - M.: RTU MIREA, 2018. - – Access mode: http://library.mirea.ru/secret/06032019/1925.iso | | |
| 5. |  | Bush A. A. Tekhnologiya keramicheskih materialov, osobennosti polucheniya keramiki VTSP fazy YBa<sub>2</sub> Su<sub>3</sub> O<sub>7-y</sub>:Ucheb. posobie. - M.: MIREA, 2000. - 80 s. | | |
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| **6.4. RECOMMENDED LIST OF MODERN PROFESSIONAL DATABASES AND INFORMATION REFERENCE SYSTEMS** | | | | |
| 1. |  | Materials Science Information Portal http://www.materialstoday.com | | |
| 2. |  | Website of the PTI Department of Nanoelectronics https://fks.mirea.ru | | |
| 3. |  | Chemical Science and Education in Russia  http://www.chem.msu.su/rus | | |
| 4. |  | HiMik.ru - website about chemistry http://www.xumuk.ru | | |
| 5. |  | Database Web of Science  http://www.webofknowledge.com | | |
| 6. |  | News and analytical portal "Vremya elektroniki "  http://www.russianelectronics.ru | | |
| 7. |  | Journal «Nano- and Microsystem Technology»  http://www.microsystems.ru | | |
| 8. |  | National Research Center «Kurchatov Institute»  http://www.kcsni.nrcki.ru | | |
| 9. |  | Elektronika NTB - scientific and technical journal  http://www.electronics.ru | | |
| 10. |  | Russian Technological Journal  https://www.rtj.mirea.ru | | |
| 11. |  | Information portal of the International Citation System Scopus  https://www.scopus.com | | |
| 12. |  | Scientific Electronic Library http://www.elibrary.ru | | |
| 13. |  | Information portal «Popular nanotechnologies» http://www.popnano.ru | | |
| 14. |  | Electronic fund of legal and regulatory technical documentation Tekhnoexpert http://www.docs.cntd.ru | | |
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| **6.5. METHODICAL INSTRUCTIONS FOR STUDENTS STUDYING THE DISCIPLINE (MODULE)** | | | | |
| The student’s independent work is aimed at preparing for academic classes and at developing knowledge, skills and abilities provided for in the discipline program.  In accordance with the curriculum, the discipline may include Lectures, practical classes and Laboratory work, as well as the execution and defense of a course project (work). Successful study of the discipline requires attending all types of classes, completing teacher assignments and familiarization with basic and additional literature. Depending on the activities provided for in the curriculum and section 4 of this program, the student chooses methodological guidelines for independent work from the ones listed below.  When preparing for lecture classes, students need to:  before the next lecture, it is necessary to review the summary of the material of the previous Lectures. If there are difficulties in perceiving the material, you should refer to the main literary sources. | | | | |

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| If it was not possible to understand the material again, then contact the lecturer (according to the schedule of his consultations) or the teacher in practical classes.  Practical classes complete the study of the most important topics of the discipline. They serve to consolidate the studied material, develop the skills and abilities of preparing reports, messages, gaining experience in oral public speeches, conducting discussions, argumentation and defending the propositions put forward, as well as to monitor the degree of readiness of students in the discipline being studied by the teacher.  When preparing for a practical lesson, students have the opportunity to use the advice of a teacher.  When preparing for practical classes, students need to:  bring with you the literature recommended by the teacher for a specific lesson;  before the next practical lesson on the recommended literary sources, work out the theoretical material corresponding to the topic of the lesson;  at the beginning of classes, ask the teacher questions about the material that caused difficulties in understanding and mastering it when solving tasks set for independent solution;  during the seminar, give specific, clear answers to the substance of the questions;  at the training session, bring each task to the final solution, demonstrate an understanding of the calculations (analyses, situations), in case of difficulties, contact the teacher.  Students who have missed classes (regardless of the reasons), who do not have a written solution to problems or are not prepared for this practical lesson, are recommended to come to the teacher’s consultation no later than 2 weeks and report on the topic studied in the lesson.  The methodological guidelines necessary for studying and passing the discipline are given as part of the educational program. | | |
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| **6.6. METHODOLOGICAL RECOMMENDATIONS FOR THE TRAINING OF PERSONS WITH LIMITED HEALTH OPPORTUNITIES AND THE DISABLED** | | |
| The development of the discipline by students with disabilities can be organized both jointly with other students and in separate groups. Special conditions are assumed for students with disabilities to receive education.  The teaching staff gets acquainted with the psychological and physiological characteristics of students with disabilities and persons with disabilities, individual rehabilitation programs for the disabled (if available). If necessary, additional teaching support is provided by tutors, psychologists, social workers, trained assistants.  In accordance with the methodological recommendations of the Ministry of Education and Science of the Russian Federation (approved April 8, 2014 N AK-44/05vn), the course is supposed to use socially active and reflective teaching methods, technologies of socio-cultural rehabilitation in order to assist in establishing full-fledged interpersonal relationships with other students, creating a comfortable psychological climate in the student group. Selection and development of educational materials are made taking into account the provision of material in various forms: auditory, visual, using special technical means and information systems.  Mediamaterials should also be used and adapted taking into account the individual characteristics of the training of persons with disabilities.  The development of the discipline by persons with disabilities is carried out using general and special purpose teaching tools (personal and collective use). Material and technical support provides for the adaptation of classrooms to the needs of persons with disabilities.  The form of certification for students with disabilities is established taking into account individual psychophysical characteristics. For students with HIA, an accessible form of assignment of assessment tools is provided, namely:  - in printed or electronic form (for persons with disorders of the musculoskeletal system); | | |

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| - in printed or electronic form with enlarged font and contrast (for persons with hearing, speech, vision impairments);  - reading the task aloud by the assistant (for visually impaired persons).  Students with disabilities have increased time to prepare answers to control questions. For such students, an accessible form of providing answers to tasks is provided, namely:  - written on paper or a set of answers on a computer (for persons with hearing and speech impairments);  - choosing an answer from possible options using the services of an assistant (for people with musculoskeletal disorders);  - oral interview (for persons with visual impairments, musculoskeletal system).  If necessary, for students with disabilities, the procedure for evaluating learning outcomes can be carried out in several stages. |