**CONDENSED MATTER PHYSICS**

**1. GENERAL CHARACTERISTICS OF THE DISCIPLINE**

The discipline programme is compiled in accordance with the Federal State Standards of Higher Education

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| --- | --- | --- | --- |
| Code of major | Major/direction | Details of the order of the Ministry of Education and Science of the Russian Federation on approval and putting into effect the Federal State Standards of Higher Education | |
| Date | Number of order |
| 03.06.01 | Physics and Astronomy/  01.04.07 - condensed matter physics | 30 July 2014  With amendments dated 30 April 2015 | 867  Amendments  464 |

**1.1. Objectives of the discipline**

The objective of the Condensed Matter Physics discipline is to acquire basic professional competences during an in-depth study of the problems and issues facing researchers at the present time in the field of the condensed matter physics.

**1.2. The discipline in the structure of the educational activities and the principal educational programme**

The Condensed Matter Physics discipline refers to Section B.1 of the elective part of the Principal Educational Programme of the postgraduate course and is aimed at preparing for the qualifying examinations for the Ph.D. degree.

As a result of mastering the discipline, a student should master the following competences:

**Universal Competencies:**

the ability to critically analyse and evaluate current scientific achievements, generate new ideas for solving research and practical problems, also in inter-disciplinary areas (Universal Competence-1);

the ability to plan and solve their own professional and personal development problems (Universal Competence-5);

**Professional Competences:**

the ability to feel at home in the fundamental sections of physics necessary for solving research problems in areas corresponding to the chosen direction, i.e. theoretical physics, condensed matter physics, physics of magnetic phenomena, thermal physics and theoretical heat engineering (Professional Competence-1);

the ability to use the knowledge of contemporary problems of physics, the latest achievements of physics in their research activities (Professional Competence-2);

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| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Discipline** | **Semester** | **Period used to master the discipline** | | | | | | |
| **In-class learning** | | | | **Self-guided work** | **Discipline attestation (test, exam)** | **Hour/credit, total** |
| **Total** | **Lectures** | **Practical exercises** | **Laboratory work** |
| Condensed Matter Physics | 6 | 4 | 4 |  |  | 104 | Test, semester 6 | 108/3 |
| **Period of mastering, total** | | **4** | **4** |  |  | **104** |  | **108/3** |

**3. CONTENTS OF THE DISCIPLINE**

**3.1 Scope and content of the discipline**

|  |  |  |  |
| --- | --- | --- | --- |
| **No** | **Subject, section** | **Work input** | |
| **Hours** | **Credits** |
| 1 | Crystal lattice. Symmetry of crystals. Symbols of crystalline planes and straight lines. The reciprocal lattice. | 2 |  |
| 2 | Types of bonds in solids. The ionisation potential. Bonding energy. Molecular, ionic and covalent crystals. | 8 |  |
| 3 | Point defects in solids, i.e. thermal, radiation. Dislocations. | 8 |  |
| 4 | Mechanical properties of solids. Elastic and plastic deformations. | 8 |  |
| 5 | Electrical conductivity. The Drude-Lorentz model. Quantum mechanical description. One-electron approximation. | 8 |  |
| 6 | Electron in periodic potential: Bloch wave function. The Brillouin zone. The density of states of an electron in the *k* space. | 8 |  |
| 7 | Zone energy spectrum of electrons in a crystal. The Kronig-Penney model. | 8 |  |
| 8 | Filling zones with electrons. Metals, dielectrics and semiconductors. The effective mass of an electron. Electrons and holes. | 8 |  |
| 9 | Levels of impurity atoms in semiconductors. Donors, acceptors. | 6 |  |
| 10 | Surface localised states. Their role in the overall conductivity of the crystal. | 6 |  |
| 11 | The intrinsic conductivity of semiconductors. Non-degenerate and degenerate carrier gas. | 6 |  |
| 12 | Impurity conductivity of semiconductors. The temperature dependence of the carrier concentration in a semiconductor and the determination of band parameters on its basis. | 6 |  |
| 13 | Experimental methods for studying the characteristics of the band spectrum. Hall effect, determination of carrier concentration and mobility. General concepts of the Hall’s quantum effect. |  |  |
| 14 | *p-n* transition from the point of view of the band structure. The device of the solar cell. |  |  |
| 15 | Conductivity of semiconductors in strong electric fields. |  |  |
| 16 | Superconductivity: phenomenology. Traditional and high-temperature superconductors. |  |  |
| 17 | The Josephson effect. SQUID (Superconducting Quantum Interference Device) and its applications. |  |  |
| 18 | Explanation of the superconductivity effect. |  |  |
|  | **TOTAL** | **108** | **3** |

**3.2. Distribution of the amount of study time for the discipline by topic and type of work**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| No | Subject, section of discipline | Amount of time assigned for the discipline study,credit/hour | | | | | | |
| In-class learning | | | | | Self-guided work | Section and subject, total |
| total | Including lectures | Including seminar/ practical exercises | | **Including laboratory work** |
| 1 | Crystal lattice. Symmetry of crystals. Symbols of crystalline planes and straight lines. The reciprocal lattice. | 2 | 2 |  | |  |  | 2 |
| 2 | Types of bonds in solids. The ionisation potential. Bond energy. Molecular, ionic and covalent crystals. |  |  |  | |  | 8 | 8 |
| 3 | Point defects in solids, i.e. thermal, radiation. Dislocations. |  |  |  | |  | 8 | 8 |
| 4 | Mechanical properties of solids. Elastic and plastic deformations. |  |  |  | |  | 8 | 8 |
| 5 | Electrical conductivity. The Drude-Lorentz model. Quantum mechanical description. One-electron approximation. | 2 | 2 |  | |  | 6 | 8 |
| б | Electron in periodic potential: Bloch wave function. Brillouin zone. The density of states of an electron in the *k* space |  |  |  | |  | 8 | 8 |
| 7 | Zone energy spectrum of electrons in a crystal. The Kronig-Penney model. |  |  |  | |  | 8 | 8 |
| 8 | Filling zones with electrons. Metals, dielectrics and semiconductors. The effective mass of an electron. Electrons and holes. |  |  |  | |  | 8 | 8 |
| 9 | The levels of impurity atoms in semiconductors. Donors, acceptors. |  |  |  | |  | 6 | 6 |
| 10 | Surface localised states. Their role in the overall conductivity of a crystal. |  |  |  | |  | 6 | 6 |
| 11 | The intrinsic conductivity of semiconductors. Non-degenerate and degenerate carrier gas. |  |  |  | |  | 6 | 6 |
| 12 | Impurity conductivity of semiconductors. The temperature dependence of the carrier concentration in a semiconductor and the determination of band parameters on its basis. |  |  |  | |  | 6 | 6 |
| 13 | Experimental methods for studying the characteristics of the band spectrum. Hall effect, determination of the carrier concentration and mobility. General concepts of the Hall’s quantum effect. |  |  |  | |  | 6 | 6 |
| 14 | *p-n* transition from the point of view of the band structure. The composition of a solar cell. |  |  |  | |  | 6 | 6 |
| 15 | Conductivity of semiconductors in strong electric fields. |  |  |  | |  | 4 | 4 |
| 16 | Superconductivity, i.e. phenomenology. Traditional and high-temperature superconductors. |  |  |  | |  | 4 | 4 |
| 17 | The Josephson effect.  SQUID and its applications. |  |  |  | |  | 4 | 4 |
| 18 | Explanation of the superconductivity effect. |  |  |  | |  | 4 | 4 |
| Discipline, total | | **4** | **4** | |  |  | **104** | **108** |

**3.3. Self-guided work of post-graduate students**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Sections and topics of the work programme for independent study** | | **List of tasks for the self-guided work (research papers, reports, translations, calculations, experiment planning etc.)** | | **Work input** | | | |
| Hour | | Credit | |
| Types of bonds in solids. The ionisation potential. Bond energy. Molecular, ionic and covalent crystals. | | Working with the recommended literature, analysis of abstract journals and electronic sources taking into account the content of the discipline (writing compendia). | | 8 | |  | |
| Point defects in solids, i.e. thermal, radiation. Dislocations. | | Working with the recommended literature, analysis of abstract journals and electronic sources taking into account the content of the discipline (writing compendia). | | 8 | |  | |
| Mechanical properties of solids. Elastic and plastic deformations. | | Working with the recommended literature, analysis of abstract journals and electronic sources taking into account the content of the discipline (writing compendia). | | 12 | |  | |
| Electrical conductivity, Drude-Lorentz model. Quantum mechanical description. One-electron approximation. | | Working with the recommended literature, analysis of abstract journals and electronic sources taking into account the content of the discipline (writing compendia). | | 12 | |  | |
| Electron in the periodic potential, the Bloch wave function. Brillouin zone. The density of states of an electron in the *k* space. | | Working with the recommended literature, analysis of abstract journals and electronic sources taking into account the content of the discipline (writing compendia). | | 10 | |  | |
| Zone energy spectrum of electrons in a crystal. The Kronig-Penney model.  Filling zones with electrons. Metals, dielectrics, semiconductors. The effective mass of an electron. Electrons and holes. | | Working with the recommended literature, analysis of abstract journals and electronic sources taking into account the content of the discipline (writing compendia). | | 8 | |  | |
| Levels of impurity atoms in semiconductors. Donors, acceptors. | | Working with the recommended literature, analysis of abstract journals and electronic sources taking into account the content of the discipline (writing compendia). | | 10 | |  | |
| Surface localised states. Their role in the overall conductivity of a crystal. | Working with the recommended literature, analysis of abstract journals and electronic sources taking into account the content of the discipline (writing compendia). | | 10 | |  | |
| The intrinsic conductivity of semiconductors. Non-degenerate and degenerate carrier gas. | Working with the recommended literature, analysis of abstract journals and electronic sources taking into account the content of the discipline (writing compendia). | | 10 | |  | |
| Impurity conductivity of semiconductors. The temperature dependence of the carrier concentration in a semiconductor and the determination of band parameters on its basis. | Working with the recommended literature, analysis of abstract journals and electronic sources taking into account the content of the discipline (writing compendia). | | 8 | |  | |
| Experimental methods for studying the characteristics of the band spectrum. Hall effect, determination of the carrier concentration and mobility. General concepts of the Hall’s quantum effect. | Working with the recommended literature, analysis of abstract journals and electronic sources taking into account the content of the discipline (writing compendia). | | 8 | |  | |
| *p-n* the transition from the point of view of the band structure. The composition of a solar cell. | Working with the recommended literature, analysis of abstract journals and electronic sources taking into account the content of the discipline (writing compendia). | | 6 | |  | |
| Conductivity of semiconductors in strong electric fields. | Working with the recommended literature, analysis of abstract journals and electronic sources taking into account the content of the discipline (writing compendia). | | 6 | |  | |
| Superconductivity: phenomenology. Traditional and high-temperature superconductors. | Working with the recommended literature, analysis of abstract journals and electronic sources taking into account the content of the discipline (writing compendia). | | 4 | |  | |
| The Josephson effect. SQUID and its applications. | Working with the recommended literature, analysis of abstract journals and electronic sources taking into account the content of the discipline (writing compendia). | | 4 | |  | |
| Explanation of the superconductivity effect. | Working with the recommended literature, analysis of abstract journals and electronic sources taking into account the content of the discipline (writing compendia). | |  | |  | |
| **TOTAL** | | | **104** | |  | |

**4. DISCIPLINE LEARNING OUTCOME REQUIREMENTS**

An objective assessment of the level of compliance of the learning outcomes with the principal educational programme learning requirements is secured by a set of developed criteria (indicators) for assessing the knowledge acquisition, skills development and experience in performing the professional tasks.

|  |  |  |  |
| --- | --- | --- | --- |
| Competence components | Features of the level of mastering competence components | | |
| threshold level | higher level | high level |
| Knowledge | A post-graduate student demonstrates the acquaintance knowledge, copy knowledge, i.e. recognises objects, phenomena and concepts, finds some differences in them, shows the knowledge of the sources of information, can independently carry out reproductive actions on knowledge by self-reproduction and application of the information. | A post-graduate student demonstrates the analytical knowledge, i.e. confidently reproduces and understands the acquired knowledge, assigns them to one or another classification group, independently arranges them, establishes interrelations between them and effectively applies them in familiar situations. | A post-graduate student can independently obtain new knowledge from the surrounding world and creatively use it to make decisions in new and unusual situations. |
| Skills | A post-graduate student is capable of correctly performing the prescribed actions following the instructions and/or an algorithm in a known situation, independently performing actions to address typical issues that require a choice from among the known methods, in predictably changing situations | A post-graduate student is capable of independently performing the actions (techniques, operations) to solve non-standard problems that require selection based on a combination of known methods, in an unpredictably changing situation | A post-graduate student is capable of independently performing the actions associated with solving research problems, demonstrates the creative use of skills (technologies) |
| Personal qualities | A post-graduate student has a low learning motivation, shows an indifferent, irresponsible attitude to studying and/or the assigned task. | A post-graduate student has a pronounced learning motivation and demonstrates a positive attitude towards learning and future activities, and is active. | A post-graduate student has a developed motivation for training and work, shows perseverance and enthusiasm, hard work, independence and creativity. |

**5. APPRAISAL TOOLS TO ENSURE THAT THE ACADEMIC PROGRESS CAN BE REGULARLY MONITORED AND INTERMEDIATE ATTESTATION CONDUCTED**

**The list of test questions (the verifiable competences Universal Competence-1, 5, Professional Competence-1,2)**

1. 1 Crystal lattice. Symmetry of crystals. The symbols of crystalline planes and straight lines. The reciprocal lattice.
2. Types of bonds in solids. The ionisation potential. Bond energy. Molecular, ionic and covalent crystals.
3. Point defects in solids, i.e. thermal, radiation. Dislocations.
4. Mechanical properties of solids. Elastic and plastic deformations.
5. Electrical conductivity. The Drude-Lorentz model, Quantum-mechanical description. One-electron approximation.
6. Electron in the periodic potential, i.e. the Bloch wave function, Brillouin zone. Density of electron states in k-space.
7. The zone energy spectrum of electrons in a crystal. The Kronig-Penney model.
8. Filling zones with electrons. Metals, dielectrics and semiconductors. The effective mass of an electron. Electrons and holes.
9. The levels of impurity atoms in semiconductors. Donors, acceptors.
10. The surface localised states. Their role in the general conductivity of crystals.
11. The intrinsic conductivity of semiconductors. Non-degenerate and degenerate carrier gas.
12. Impurity conductivity of semiconductors. The temperature dependence of the concentration of current carriers in a semiconductor and the determination of band parameters on its basis.
13. Experimental methods for studying the characteristics of the band spectrum. Hall effect, determination of carrier concentration and mobility. The general concepts of the Hall’s quantum effect.
14. *p-n* transition from the point of view of the band structure. The composition of a solar cell.
15. The conductivity of semiconductors in strong electric fields.
16. Superconductivity, phenomenology. Traditional high-temperature superconductors.
17. The Josephson effect. SQUID and its applications.
18. Explanation of the superconductivity effect.

**Electronic educational resources**

Zonal Scientific Library http://library.urfu.ru/

Catalogs of the library http://library.nrfn.ru/about/department/catalog/rescatalog/

Electronic catalog http://library.urfu.ru/resourees/ec/

Resources http://Iibrary.urfu.ru/resources

Search http://library.urfii.ru/search

**Databases, Information and reference systems as well as Search Engines**

ScienceDirect Electronic Resources: http://www.sciencedirect.com

Web of Science: http://apps.webotoowledge.com

ScienceDirect Electronic Resources: http://www.scifinder.com

Web of Science: http://reax.vs.org