**THEORETICAL PHYSICS**

**1. GENERAL CHARACTERISTICS OF DISCIPLINE**

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

|  |  |  |  |
| --- | --- | --- | --- |
| Code of field  of study | Name of field of study/specialisation | Details of the order of the Ministry of Education and Science of the Russian Federation on approval and commissioning of the Federal State Standard of Higher Education | |
| Date | Number of order |
| 03.06.01 | Physics and astronomy/  01.04.02 - theoretical physics | 30 July 2014 With changes dated 30 April 2015 | 867  Amendments 464 |

**1.1. Objectives of the discipline**

The discipline Theoretical Physics is aimed at acquiring the basic professional competencies during an in-depth study of the main modern methods of theoretical physics, model theories of various physical properties, primarily condensed and strongly correlated media.

**1.2. Place of the discipline in the educational activities and the main educational programme**

The Theoretical Physics discipline refers to Section B of the variative part of the Main Educational Programme for the Postgraduate Course and is aimed at preparing for passing the qualifying examinations for the Ph.D. degree.

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

**Universal Competencies:**

the ability to critically analyse and evaluate current scientific achievements, generate new ideas in 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 to solve research problems in areas corresponding to the chosen area of study, theoretical physics, condensed matter physics, physics of magnetic phenomena, thermophysics and theoretical heat engineering (Professional Competence-1);

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

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **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** |
| Theoretical 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 | **Introduction.** The history and actual problems of theoretical physics. Condensed state theory. Strongly correlated systems. | 2 |  |
| 2 | **Theory and group methods.** Symmetry and conservation laws. Symmetry groups. Wigner’s theorem. Irreducible Tensor Operators Method of the rotation group. Wigner-Eckart theorem. Fundamentals of the graphic technique of Yudis-Levinson. Point groups. The irreducible tensor operators method of the cube group.  Spatial groups of crystals. Irreducible representations. Magnetic symmetry groups. | 10 |  |
| 3 | **Theory of phase transitions and critical phenomena.**  Elements of the thermodynamic description of the condensed matter. Generalised susceptibilities. Spontaneous symmetry breaking, quasi-mean and anomalous Green’s functions. The Landau theory of phase transitions of the second kind, order parameters, fluctuations, functional integration. Critical indices and scaling. Wilson’s renormalisation group. Epsilon and 1/n-expansion for critical indices. Symmetry of crystals and phase transitions. Lifshitz criteria. Orientational phase transitions. Peculiarities of the behaviour of susceptibilities in phase transitions. | 8 |  |
| 4 | **Elements of quantum statistical mechanics.**  Statistical operator and thermodynamic functions. Statistical operators of particle sets. The Wick-Bloch-Dominicis theorem. Degeneracy of states and quasi-averages.  Quantum field theory methods at T = 0. Green’s functions, physical meaning, analytical properties. Basic principles of diagram techniques, rules for constructing diagrams for various types of interactions. Dyson equation, vertex part, many-particle Green’s functions, ground-state energy. Diagram technique at finite temperatures. Temperature (Matsubara) Green's functions, connection with the time Green’s functions. Diagram techniques for various types of interaction. Thermodynamic potential. Fundamentals of the Keldysh techniques. Two-time Green’s functions. Delayed, advanced and causal Green’s functions. Spectral representations and sum rules. Chains of equations of motion and uncoupling methods. The system’s reaction to the external action, the Kubo formula. | 12 |  |
| 5 | **Multielectron atoms in crystals.**  Classification of the states of a free atom. Electrostatic interactions. Spin-orbit interaction. Theory of the crystal field (CF). Multielectron configurations in the scheme of a strong cubic CF. High and low-spin states of ions with an unfilled 3d shell. Average CF scheme. Crystalline 28 + 1G terms. Weak CF scheme. The Stevens' operator-equivalent method. Theory of single-ion magnetic anisotropy of rare-earth ions and ions of the iron group. Ultrafine interactions.  Interaction of atoms in crystals. Exchange and exchange-relativistic interactions. Spin models of Heisenberg, Ising, Dzyaloshinsky-Moriya. Non-Heisenberg spin Hamiltonians. | 12 |  |
| 6 | **Electronic theory of metals.**  Fundamentals of the Fermi liquid theory. Landau phenomenological expression. Proof of the main relations of the Fermi liquid theory by the Green’s function method. Coulomb systems and screening, low- and high density approximations. Kinetic Boltzmann equation for electrons in a metal. Electrical conductivity of metals. Scattering of electrons in metals by impurities, phonons, electrons. Temperature dependences of electrical conductivity and electronic thermal conductivity. Rule Matisseen. The Kondo effect. Influence of the topology of the Fermi surface on the electrical conductivity of a metal. Lifshtz's formula, Electronic properties of metals in a magnetic field. Levels of Landau. Oscillation of magnetic susceptibility. Effects of Einstein - de Haas and Shubnikov. Cyclotron resonance. Longitudinal magnetoresistance. Strong and weak magnetic fields. Influence of the topology of the Fermi surface on the electrical conductivity of metals in a magnetic field. Galvanomagnetic effects. Transverse magnetoresistance. Magneto-oscillation effects. The classical and quantum Hall effects. |  |  |
| 7 | **Methods of the band theories of crystals.**  Hamiltonian systems of electrons and ions. Approximations of the model. Adiabatic approximation. The Hartree-Fock method. Approximation of a strong and weak connection. Brillouin zones. The Fermi surface.  Methods for calculating the band structure, the augmented plane wave method. Pseudopotentials. Surfaces of Fermi *d* and *f* metals. Theory of the electron density functional (DFT). The approximations of LDA, LSDA, LDA + U. The dynamic mean field theory (DMFT) | 8 |  |
| 8 | **Lattice vibrations, phonons.**  Symmetry of crystals and classification of phonon modes. Acoustic and optical phonons. The dispersion law of phonons. Elements of the kinetics and thermodynamics of phonon gas at low temperatures. Kinetic Boltzmann equation for a phonon gas. Approximation of the relaxation time. Normal processes and carry-over processes. Phonon gas in an ideal dielectric. The second sound, the conditions of its occurrence. The potential of inter-molecular interaction. Phonon heat capacity and thermal conductivity. Spectroscopy of phonons. Quantum crystals. The stability condition of the crystalline state. de Burr parameter. Quantum diffusion. Vacansions. Impuritons.  The model of hard ions and the shell model of a crystal. Electron-vibrational interactions. The Hamiltonian. Electron-lattice relaxation. The theory of screening effects. The Jahn-Teller effect theory. The polarons. Orbital ordering. Cooperative Jahn-Teller ordering. | 10 |  |
| 9 | **The superconductivity theory.**  The Meissner effect. The critical field and critical current. Thermodynamics of the phase transition from the normal state to the superconducting state. The depth of penetration of the magnetic field into the sample. Stream quantisation. Coherence length. The Ginzburg-Landau equation. Two types of superconductors. Abrikosov vortices. The Josephson effect theory. Microscopic theory of the stationary Josephson current. The non-stationary Josephson effect. The tunnelling Hamiltonian method. Electrodynamics of weak superconductivity. Quantum interference. Non-linear wave equation. Interaction of electrons through virtual phonons, Cooper pairing. The Bardeen-Cooper-Schrieffer theory. The Bogolyubov u-v-transformation method. The Gor'kov equations. Energy gap. Superconducting transition temperature. Models of exciton superconductivity Little and Ginzburg. Basic model theory of high-temperature superconductivity. | 10 |  |
| 10 | **Selected points of the theory of low-dimensional systems.** Two-dimensional electronic systems. Wigner crystallisation. Topology of two-dimensional systems. Spin 2D models. Topological defects. Whirlwinds, skyrmions. The Veresinsky-Kosterlitz-Thouless theory, 1D and 2D Ising models. Quantum magnets. Magnetic frustration. Incompatible structures. Spin-helical systems, helimagnetics. | 8 |  |
| 11 | **Elements of the theory of disordered systems.**  The classification of disordered systems. Elementary excitations in disordered media. Methods of description. Density of states. Basic ideas about the Anderson localisation, scaling theory. General characteristics of the spectrum of the elementary excitations in disordered media. Fluctuation boundaries of the spectrum. The structure of the spectrum near the fluctuation boundaries. Limits of mobility. Electrons in the field of random impurities, ladder approximation, quantum and Coulomb corrections. Phonons in disordered systems. Excitons in disordered systems. Spin glasses. The Edwards-Anderson model. The Parisi theory, | 8 |  |
| 12 | **Standard models and methods of the theory of strongly correlated systems.**  Shubin-Vonsovsky s-d model. Bogolyubov-Levdin model. Anderson model, Hubbard model. Mean field approximations (+RPA). The Hartree-Fock approximation. Solution of the simplest realisations of the Anderson and Hubbard models in the Hartree-Fock approximation. The Monte Carlo method. Classic and quantum options. Examples of solving problems in the theory of strongly correlated systems. Quantum magnets. Spin Hamiltonians, the localised and collectivised models. Representations of spin operators by second quantisation operators. Wick’s theorem for spin operators and the basis of diagram technique. Method of the molecular field, spin waves. The Hubbard model, strongly correlated systems, the Mott transition. Pseudospin formalism in strongly correlated systems. | 10 |  |
|  | **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 | Introduction | 2 | 2 |  | |  |  | 2 |
| 2 | Group and theoretical methods |  |  |  | |  | 10 | 10 |
| 3 | Theory of phase transitions and critical phenomena |  |  |  | |  | 8 | 8 |
| 4 | Elements of quantum statistical mechanics |  |  |  | |  | 12 | 12 |
| 5 | Multielectron atoms in crystals |  |  |  | |  | 12 | 12 |
| б | Electronic theory of metals |  |  |  | |  | 10 | 10 |
| 7 | Methods of the band theory of crystals |  |  |  | |  | 8 | 8 |
| 8 | Lattice vibrations, phonons |  |  |  | |  | 10 | 10 |
| 9 | Superconductivity theory |  |  |  | |  | 10 | 10 |
| 10 | Selected points in the theory of low-dimensional systems |  |  |  | |  | 8 | 8 |
| 11 | Elements of the theory of disordered systems |  |  |  | |  | 8 | 8 |
| 12 | Standard models and methods of the theory of strongly correlated systems | 2 | 2 |  | |  | 8 | 10 |
| 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 | |
| **Group and theoretical methods.**  Symmetry and conservation laws. Symmetry groups. Wigner’s theorem. Method of irreducible tensor operators of the rotation group. Wigner-Eckart theorem. Fundamentals of the graphic technique by Yutsis-Levinson. Point groups. The method of irreducible tensor operators of the cube group.  Spatial groups of crystals. Irreducible representations. Groups of magnetic symmetry. | | Working with the recommended literature, analysis of abstract journals and electronic sources taking into account the content of the discipline (writing compendia). | | 10 | |  | |
| **Theories of phase transitions and critical phenomena.**  Elements of the thermodynamic description of the condensed matter. Generalised susceptibilities. Spontaneous symmetry breaking, quasi-averages and anomalous Green’s functions. The Landau theory of phase transitions of the second kind, order parameters, fluctuations, functional integration. Critical indexes and scaling. Renormalisation group of Wilson, Epsilon and 1/n expansion for critical exponents. Symmetry of crystals and phase transitions. Lifshitz criteria. Orientational phase transitions. Peculiarities of the behaviour of susceptibilities in phase transitions | | Working with the recommended literature, analysis of abstract journals and electronic sources taking into account the content of the discipline (writing compendia). | | 8 | |  | |
| **Elements of quantum statistical mechanics.**  Statistical operator and thermodynamic functions. Statistical operators of particle sets. The Wick-Bloch-de Dominicis theorem. Degeneracy of states and quasi-averages.  Methods of quantum field theory at T=0. Green’s functions, physical meaning, analytical properties. Basic principles of diagram technique, rules for constructing diagrams for various types of interactions. Dyson equation, vertex part, multiparticle Green’s functions, ground-state energy. Diagram technique at finite temperatures. Temperature (Matsubara) Green’s functions, connection with the time Green’s functions. Diagram technique for various types of interaction. Thermodynamic potential. Fundamentals of the Keldysh technique. Green’s two-time functions. Delayed, advanced and causal functions of Green. Spectral representations and sum rules. Chains of equations of motion and methods of uncoupling. The system excitation response, the Kubo formula. | | Working with the recommended literature, analysis of abstract journals and electronic sources taking into account the content of the discipline (writing compendia). | | 12 | |  | |
| **Multielectron atoms in crystals.**  Classification of the states of a free atom. Electrostatic interactions. Spinorbit interaction. Theory of the crystal field (CF). Multielectron configurations in the scheme of strong cubic CF. High and low-spin states of ions with an unfilled 3 d shell, Scheme of the average CF. Crystalline 28 + 1G terms, Scheme of weak CF. The method of equivalent operators of Stevens. Theory of single-ion magnetic anisotropy of rare-earth ions and ions of the iron group. Superfluidity interactions.  Interaction of atoms in crystals. Exchange and exchange-relativistic interactions. Spin models of Heisenberg, Ising, Dzyaloshinsky-Moriya. Non-Heisenberg spin Hamiltonians. | | Working with the recommended literature, analysis of abstract journals and electronic sources taking into account the content of the discipline (writing compendia). | | 12 | |  | |
| **Electronic theory of metals.**  Fundamentals of Fermi-liquid theories. Phenomenological Landau formulation, Proof of the main relations of the Fermi-liquid theory by the Green’s function method. Coulomb systems and screening, approximations of small and large density. Kinetic Boltzmann equation for electrons in a metal. Electrical conductivity of metals. Scattering of electrons in metals by impurities, phonons and electrons. Temperature dependences of electrical conductivity and electronic thermal conductivity. Rule Matisseen. The Kondo effect. Influence of the topology of the Fermi surface on the electrical conductivity of a metal. The Liftshits formula. Electronic properties of metals in a magnetic field. Landau levels. Oscillation of magnetic susceptibility. Effects of Einstein - de Haas and Shubnikov, Cyclotron resonance. Longitudinal magnetoresistance. Strong and weak magnetic fields. Influence of the topology of the Fermi surface on the electrical conductivity of metals in a magnetic field. Galvanomagnetic effects. Transverse magnetoresistance. Magneto-oscillation effects. The classical and quantum Hall effects. | | Working with the recommended literature, analysis of abstract journals and electronic sources taking into account the content of the discipline (writing compendia). | | 10 | |  | |
| **Methods of the band theory of crystals.**  Hamiltonian system of electrons and ions. Approximations of the model. Adiabatic approximation. The Hartree-Fock method. Approximation of a strong and weak connection. The Brillouin zones. The Fermi surface. Methods of calculating the band structure, the method of attached plane waves. Pseudopotentials. Surfaces of Fermi d and / metals. Theory of the electron density functional (DFT), Approximation of LDA, LSDA, LDA + U. Theory of the dynamic mean field. | | Working with the recommended literature, analysis of abstract journals and electronic sources taking into account the content of the discipline (writing compendia). | | 8 | |  | |
| **Lattice vibrations, phonols.**  Symmetry of crystals and classification of phonon modes. Acoustic and optical phonons. The dispersion law of phonons. Elements of the kinetics and thermodynamics of phonon gas at low temperatures. Kinetic Boltzmann equation for a phonon gas. Approximation of the relaxation time. Normal processes and carry-over processes. Phonon gas in an ideal dielectric. The second sound, the conditions of its occurrence. The potential of intermolecular interaction. Phonon heat capacity and thermal conductivity. Spectroscopy of phonons. Quantum crystals. The stability condition of the crystalline state. de Burr parameter. Quantum diffusion. Vacansions. Impuritons.  The model of hard ions and the shell model of a crystal. Electron-vibrational interactions. The Hamiltonian. Electron-lattice relaxation. Theory of screening effects. The theory of the Jahn-Teller effect. The polarons. Orbital ordering. Cooperative Jahn-Teller ordering. | | Working with the recommended literature, analysis of abstract journals and electronic sources taking into account the content of the discipline (writing compendia). | | 10 | |  | |
| **The theory of superconductivity.**  The Meissner effect. Critical field and critical current. Thermodynamics of the phase transition from the normal state to the superconducting state. The depth of penetration of the magnetic field into the sample. Stream quantisation. Coherence length. The Ginzburg-Landau equation. Two kinds of superconductors. Vortices of Abrikosov. Theory of the Josephson effect. Microscopic theory of stationary Josephson current. The non-stationary Josephson effect. The non-stationary Josephson effect. The tunnelling Hamiltonian method. Electrodynamics of weak superconductivity. Quantum interference. Non-linear wave equation. Interaction of electrons through virtual phonons, Cooper pairing, Bardeen–Cooper–Schrieffer. The Bogolyubov u-v-transformation method, Gorkov equations, Energy gap. Superconducting transition temperature. Little and Ginzburg models of exciton superconductivity. Basic model theories of high-temperature superconductivity. | Working with the recommended literature, analysis of abstract journals and electronic sources taking into account the content of the discipline (writing compendia). | | 10 | |  | |
| **Selected problems in the theory of low-dimensional systems.**  Two-dimensional electronic systems. Crystallization of Wigner,  Topology of two-dimensional systems. Spin 2D models. Topological defects. Whirlwinds, Skyrmions. The Berezinskii-Kosterlitz-Thouless theory. 1D and 2D Ising model. Quantum magnets. Magnetic frustration. Incompatible structures. Spin-helical systems, helimagnets. | Working with the recommended literature, analysis of abstract journals and electronic sources taking into account the content of the discipline (writing compendia). | | 8 | |  | |
| **Elements of the theory of disordered systems.**  Classification of disordered systems. Elementary excitations in disordered media. Methods of description. Density of states. Basic ideas of Anderson about localisation, the scaling theory. General characteristics of the spectrum of elementary excitations in disordered media. Fluctuation boundaries of the spectrum. The structure of the spectrum near the fluctuation boundaries. Limits of mobility. Electrons in the field of random impurities, ladder approximation, quantum and Coulomb corrections. Phonons in disordered systems. Excitons in disordered systems. Spin glasses. The Edwards-Anderson model. The Parisi theory. | Working with the recommended literature, analysis of abstract journals and electronic sources taking into account the content of the discipline (writing compendia). | | 8 | |  | |
| **Standard models and methods of the theory of silnocorrelated systems.**  s-d model of Shubin-Vonsovsky. Bogolyubov-Levdin model. Anderson model. The Hubbard model. Approximations of the mean field (+ RPA). The Hartree-Fock approximation. Solution of the simplest realizations of the Anderson and Hubbard models in the Hartree-Fock approximation, Monte Carlo method. Classic and quantum options. Examples of solving problems in the theory of strongly correlated systems. Quantum magnets. Spin Hamiltonians, localised and collectivised model. Representations of spin operators by second quantization operators. Wick’s theorem for spin operators and the basis of diagram technique. Method of molecular field, spin waves. The Hubbard model, strongly correlated systems, the Mott transition. Pseudospin formalism in strongly correlated systems. | Working with the recommended literature, analysis of abstract journals and electronic sources taking into account the content of the discipline (writing compendia). | | 8 | |  | |
| **TOTAL** | | | **104** | |  | |

**4. DISCIPLINE LEARNING OUTCOME REQUIREMENTS**

An objective assessment of the level of compliance of the learning outcomes with the 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. **Elements of the quantum statistical mechanics.** Statistical operator and thermodynamic functions. Statistical operators of particle complexes. The Wick-Bloch-de Dominicis theorem, Degeneracy of states and quasiaverage.
2. **Methods of the quantum theory of zero at T=0.** Green's functions, physical meaning, analytic properties. Basic principles of diagram technique, rules for constructing diagrams for various types of interactions. Dyson equation, vertex part, many-particle Green's functions, ground-state energy.
3. **Diagram technique at finite temperatures.** Temperature (Matsubara) Green’s functions, connection with the time Green's functions. Diagram technique for various types of interaction. Thermodynamic potential. Fundamentals of the Keldysh technique.
4. **Two-time Green’s functions.** Delayed, advanced and causal functions of Green. Spectral representations and sum rules. Chains of equations of motion and methods of uncoupling. The reaction of the system to external influences, Kubo's formulas.
5. **Fundamentals of Fermi-liquid theories.** Phenomenological formulation of Landau. Proof of the main relations of the Fermi-liquid theory by the Green's function method. Kudon systems and screening, approximations of small and high density.
6. **The system of interacting bosons.** Basic ideas about superfluidity. The Bogolyubov u-v-transformation method in application to Bose gas. Fundamentals of Belyaev's diagram technique.
7. **The theory of superconductivity.** Cooper instability, BCS model. The Bogolyubov u-v-transformation method. The equations of Gor'kov. Thermodynamics of superconductors. The Ginzburg-Landau equations, two kinds of superconductors. The Josephson effect.
8. **Elements of the quantum theory of magnetism.** Spin Hamiltonians, the localised and collectivised model. Representations of spin operators by second quantization operators. Wick’s theorem for spin operators and the basis of diagram technique. Method of molecular field, spin waves. The Hubbard model, strongly correlated systems, the Mott transition.
9. **Theory of phase transitions and critical phenomena.** Spontaneous symmetry breaking, quasi-average and anomalous Green's functions. The Landau theory, fluctuations, functional integration. Critical indexes and scaling. Wilson's renormalization group. Epsilon and 1 / n-expansion for critical indices.
10. **Basic representations of the modern theory of disordered systems.** Electrons in the field of random impurities, ladder approximation, quantum and Coulomb corrections. Basic ideas of Anderson about the localisation, the scaling theory. The method of replicas and elementary representations of spin glasses.

**References**

1. Р.А. Lee, T.V. Ramakrishnan. Disordered Electronic Systems, Rev.Mod.Phys. 57, No.2, 287 (1985).
2. Handbook of Magnetism and advanced magnetic materials, Volume I: Fundamentals and Theory, Eds. H. Kromnueller and S. Parkin, Wiley, 2007. 700 p.
3. R.D. Mattuck. D. Johansson. Adv.Phys. 17, 509 (1968).
4. A.S. Moskvm, Spin and Pseudospin Models: Hamiltonians, Topological Excitations, The Physics of Metals and Metallography (ФММ), Vol. 95, Suppl. 1, 2003, p. 41.

**Electronic educational resources**

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

Catalogues of the library http://library.urfu.ru/about/department/catalog/rescatalog/

Electronic catalogue http://library.urfu.ru/resources/ec/

Resources http://library.urfo.ru/resources Search http://library.urfu.ru/search

**Databases, information and reference systems, and search engines**

ScienceDirect Electronic Resources: http://mvw.sciencedireet.com:

Electronic resources Web of Science: http: //apps.webofknowledge.com;

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

Electronic Resources Web of Science: http://reaxvs.org