SMART NANOSTRUCTURES AND CONDENSED MATTER PHYSICS

ENTRY TEST FOR THE MASTER PROGRAM, YEAR 2020

CONTENT

1. Quantum mechanics

1.1. Wave function and its properties.

The principle of superposition. Orthogonality, normalization and completeness of functions.

1.2. Operators of physical values.

Statistical properties of the observed values. Average values of physical quantities. Hermitian operators.

1.3. Particle free motion

Free movement of a particle. Impulse operator. Momentum eigenfunctions, normalization of eigenfunctions.

1.4. Schrödinger equation.

Hamilton operator. The continuity equation for probability density. The stationary Schrödinger equation. Discrete and continuous energy spectra.

1.5. Simultaneous measurability of physical quantities

Commutation relation. Heisenberg uncertainty principle.

1.6. The matrix formulation of quantum mechanics.

Matrix formalism of quantum mechanics. Matrices representing physical quantities.

1.7. Particle motion in a potential well.

Solutions of the stationary Schrödinger equation for one-dimensional wells. Border conditions. Tunneling through the barrier. One-dimensional barriers.

1.8. Harmonic oscillator

Energy spectrum and wave functions. Harmonic oscillator in the operator form. Wave functions of eigenstates, Hermite polynomials. Creation and annihilation operators.

1.9. Motion in a centrally symmetric field.

Momentum operator. Spherical functions. Hydrogen atom. Energy spectrum and wave functions.

1.10. Particle scattering.

Scattering amplitude, scattering cross section. Born approximation. Scattering at the Coulomb center, Rutherford formula.

1.11. Angular momentum.

The general formalism of angular momentum. Spin of the particles. Particles with spin 1/2, spinors. Spin operator, Pauli matrices.

1.12. The principle of indistinguishability of identical particles.

Symmetry of the wave function with respect to particle permutations. Bosons and fermions. Pauli principle.

2. Solid state physics

2.1.Structure of crystals

Space lattices. Translational symmetries, unit cell, Bravais lattice. Crystal systems: triclinic, monoclinic, orthorhombic, tetragonal, trigonal, hexagonal, and cubic.

2.2. Reciprocal lattice.

The main properties of the reciprocal lattice, Miller indices for planes and directions in cubic crystals.

2.3. Brillouin zones.

Brillouin zones. Definition of the first Brillouin zone and methods of its construction for crystals of different structures.

2.4. Diffraction of waves by crystals.

Study of crystal structure using wave diffraction. Wave diffraction (light, electrons, neutrons) on crystals. Interpretation of Bragg diffraction based on the concepts of the reciprocal lattice.

2.5.Spatial transformations

Symmetry in crystals. Spatial transformations of crystal symmetry (translation, rotations, reflections, mirror-rotational transformations, transformations of screw rotation and sliding reflection).

2.6. Elements of the theory of symmetry groups of crystals

Space and point groups of crystals. Real crystals: crystal systems, lattice types, crystal classes, space groups.

2.7. Electronic band structure of crystals. Electrons in a periodic potential.
Schrödinger's equation for an electron in a periodic potential field. Fermi surface.

2.8. Electronic band structure of crystals. Electrons in a weak periodic potential.
The concept of perturbation theory in quantum mechanics. The periodic potential of the lattice as a perturbation. Allowed and forbidden zones of electronic states.

2.9. Drude theory of metals.
The main principles of Drude theory of metals. Static conductivity and Hall coefficient.

2.10. Sommerfeld theory of metals.
Thermodynamic properties of free electron gas. Fermi-Dirac distribution function. Heat capacity in Sommerfeld theory of metals.

2.11. General concepts of interatomic interactions. The forces of Van der Waals.
Van der Waals interaction from the classical and quantum points of view. The binding energy in the Van der Waals interaction.

2.12. General concepts of interatomic interactions. Lennard-Jones potential.
Mutual repulsion of atoms. Lennard-Jones potential. Ion bond. Covalent bond.

Recommended books:

1. Griffiths, David (2005). Introduction to Quantum Mechanics (2nd ed.). Pearson Prentice Hall. ISBN 0131118927.
2. Cohen-Tannoudji, Claude; Diu, Bernard; Laloë, Franck (1977). Quantum Mechanics. Wiley. ISBN 978-0471164333.
3. Feynman, Richard P. (2005). The Feynman Lectures on Physics. 1, 3 (2nd ed.). Addison-Wesley. ISBN 978-0-8053-9065-0.
4. Ashcroft, N.; Mermin, D. (1976). "Chapter 7". Solid State Physics. Brooks/Cole (Thomson Learning, Inc.). ISBN 978-0030493461.
5. Hook, J.R.; Hall, H.E. (2010). Solid State Physics. Manchester Physics Series (2nd ed.). John Wiley & Sons. ISBN 9780471928041.
6. Kittel. H.; Introduction to Solid State Physics (8th ed). John Wiley & Sons. ISBN: 978-0-471-41526-8