Approved at the Academic Council meeting
of the college of New Materials and
nanotechnologies NUST MISIS,
Minutes №7-23, dated by 26.10.2023

ENTRANCE EXAMINATION CONTENT
FOR THE MASTER`S DEGREE PROGRAM IN
03.04.02 Quantum Physics for Advanced Materials Engineering

Moscow 2023

PROGRAM

admission test

« Physics »

The content of the program:

I. Explanatory Note

The purpose of the entrance examination is to establish upon entering the master's program the level of the candidate's knowledge of subject-related educational and scientific materials and compliance with the training requirements of the state educational standard of higher education.

The form and the duration of the exam. Evaluation criteria. The Master's degree program entrance exam in direction of preparation "Physics" (03.04.02) is conducted in written form.

The duration of the entrance examination is 90 minutes.

Examination poll contains 11 problems. Tasks 1-6 are graded on 0÷5 scale (5 for the entirely correct answer, 0 for the incorrect one), and require the selection of the correct answer in a sentence. Problems 7-10 are graded on 0÷15 scale and require a detailed answer, specifying the definitions of physical laws describing the phenomenon and conclusions. Problem 11 is an essay on the theme of previous scientific (technological) research and evaluated from 0 to 10 points.

The maximum amount of the total of 100 points.

As a result of the written part of the entrance test examination committee puts the final assessment as the sum of the scores received for each job.

Entrance test results are assessed on a 100 point scale. Minimum passing score, confirming the successful completion of entrance examinations, is 40.

Equipments which are allowed to use during the exam are: pen, pencil eraser and nonprogrammable calculator.

2. Examination Content Outline

Thermodynamics

1. The subject of physical chemistry. Thermodynamic system and thermodynamic parameters. State function. First law of thermodynamics. Internal energy, enthalpy, work.
2. Thermo chemical calculations. Hess's law. Reaction enthalpy dependence on temperature. Standard formation enthalpies of compounds.
3. Second law of thermodynamics. Entropy. Entropy calculation for simple processes.
4. Thermodynamic functions: Gibbs energy and Helmholtz energy. Gibbs and Helmholtz energies dependence on state parameters.
5. Gibbs-Helmholtz equation. Third law of thermodynamics.
6. Phase equilibrium. Clausius-Clapeyron relation. Saturated vapor on temperature dependence.
7. Chemical equilibrium in homogenious gas systems. Law of mass action. Reaction output calculation.
8. Chemical reaction isotherm. Equilibrium constant dependence on temperature.
9. Heterogeneous chemical reactions. Dissociation elasticity. Chemical equilibrium calculation based on tables of standard thermodynamical quantities.
10. Technological control with chemical thermodynamics.
11. Partial molar quantities. Gibbs-Duhem equation.
12. Infinitely dilute solutions. Henry and Raul laws. Solubility of gases in metal. Distribution law. Theoretical foundations of removing impurities from metal. Law of mass action.
13. Perfect solutions. Thermodynamic functions of perfect solutions. Entropy of mixing. Perfect ionic solutions, slag theory base. Melt salts solutions, mattes.
14. Real solutions. Theory of thermodynamical activity. Activity coefficient. Standart state selection. Activity dependence on temperature. Methods for activity determination.
15. Electrolyte solutions. Activity of strong electrolytes. Electromotive forces. Thermodynamics of galvanic elements. Determination of thermodynamic quantities with emf.
16. Equilibrium condition in multiphase systems. Gibbs' phase rule.
17. Phase diagrams of two component systems. Phase transitions. Phase compositions.

Kinetics

1. Surface phenomena role in intensification of technological processes of making metals and alloys.
2. Adsorption of gases. Molecular and activated adsorption.
3. Adsorption isotherm and isobar. Langmuir theory.
1. Adsorption on inhomogeneous surface.
2. Polymolecular adsorption.
3. Adsorption on liquid-gas boundary.
4. Surface tension dependence on solution composition.
5. Formal kinetics. Speed of reaction.
6. Speed constant. Order of reaction. External factors' influence on speed of reaction.
7. Speed constant dependence on temperature.
11. Activation energy. Relation of equilibrium constant with constants of direct and reverse reactions.
12. Diffusion in gases, liquids and solid bodies. Diffusion equations. Diffusion coefficient.
13. Random walk model. Diffusion mechanisms in solid bodies. Vacantion mechanism.

14. External mass transfer,
15. Internal mass transfer.
16. Diffusion in multiphase systems. Diffusion phase growth.
17. Ionic conductance. Transfer phenomena in electrolytes and ionic crystals.

Mechanics and elasticity theory

1. Principle of least action. Lagrange function. Lagrange equation.
2. Galileo relativity principle. Energy, impulse and torque conservation laws.
3. Particle motion in a one-dimensional potential field.
4. Particle motion in central field. Kepler's problem.
5. Free one-dimensional oscillations. Driven harmonic oscillations. Resonance.
6. Hamiltonian. Hamilton's equations of motion.
7. Poisson's brackets. Conservation laws.
8. Tensor of deformations. Stress tensor.
9. Hooke's law.
10. Uniform deformations.
11. Equation of motion of elastic medium. Elastic waves in isotropic medium.

Quantum mechanics

1. De Broglie's waves. Uncertainty principle. Superposition principle and wave packets.
2. The role of device in micro world measurements. Causality principle in quantum mechanics.
3. Schroedinger's equation. Stationary states. Particle in potential well.
4. General properties of harmonic oscillator: zero-point oscillations, equidistant consecutive energy levels; wave functions of stationary states.
5. Probability flux density and conservation of the probability flux. Propagation of particle through potential barrier: tunneling effect.
6. Hermitian operators. Eigenvalues and eigenfunctions of an operator of a physical quantity.
7. Probability of a given state and mean value calculations. Change of representation.
8. Torque operator. Its eigenvalues and eigenfunctions.
9. Motion in central symmetrical field. Separation of variables. Hydrogen atom and periodic system of elements.
10. Bohr-Sommerfield quasi classical approximation.
11. Particle's spin. Principle of indistinguishability of elementary particles. Pauli's principle.

3. Recommended Reading

1. L.D. Landau E.M. Lifshitz, Course of Theoretical Physics. Volume 1: Classical mechanics, 3rd edition (Elsevier, 1980, reprinted in 2005).
2. L.D. Landau E.M. Lifshitz, Course of Theoretical Physics. Volume 7: Theory of Elasticity, 3 edition (Elsevier, 1980, reprinted in 2005).
3. L.D. Landau E.M. Lifshitz, Course of Theoretical Physics. Volume 3: Quantum mechanics, 3rd edition Elsevier, 1980, reprinted in 2005.
4. Galitski, B. Karnakov, V. Kogan, Exploring Quantum Mechanics: A Collection of 700+ Solved Problems for Students, Lecturers, and Researchers, Oxford University Press, USA (April 22, 2013)
5. Claude Cohen-Tannoudji , Bernard Diu Frank Laloe, Quantum mechanics. John Wiley and Sons, Inc./Hermann (1977).

Additional Reading

1. R.P. Feynman, R.B. Leighton, M. Sands , *The Feynman Lectures on Physics,* 2nd Revised edition, Addison Wesley, vol. 1-3, 2005.
2. R.P. Feynman, R.B. Leighton, M. Sands, Vogt, *Exercises for the Feynman Lectures on Physics*, edited by Michael A. Gottlieb and Rudolf Pfeiffer, Copyright © 1963, 2013 by California Institute of Technology, Michael A. Gottlieb, and Rudolf Pfeiffer.
3. C. Kittel, W.D. Knight, M.A. Ruderman, A.C. Helmhotz, B.J. Moyer, *Mechanics,* Berkeley Physics Course, 2nd edition, Vol. .1, 1973.
4. P.A.M. Dirac The Principles of Quantum Mechanics, Oxford University Press, USA; 4 edition (February 4, 1982)
5. R.P. Feynman, R.B. Leighton, M. Sands , The Feynman Lectures on Physics, 2nd Revised edition, Addison Wesley, vol. 8-9, 2005.

Problems and solutions

I.E. Irodov, "Problems in general physics", Mir Publishers, 3rd edition, 1988.