Approved at the Academic Council meeting
of the college of Physics and Quantum Engineering
№ 9-25 from 25.12.2025

ENTRANCE EXAMINATION CONTENT

FOR THE MASTER'S DEGREE PROGRAM

CODE 03.04.02 Quantum Physics for Advanced Materials Engineering/ Квантовая физика для современной инженерии материалов

Moscow 2025

Content

1. 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.

Equipment which is allowed to use during the exam includes: pen, pencil eraser and nonprogrammable calculator.

For the foreign candidates a distant entrance examination may take place via specified platform.

2. Examination Content Outline.

Section 1. General physics

The movement of bodies. Characteristics of motion. The energy, momentum, angular momentum.
Force. Conditions of equilibrium of bodies.
Electric field. Electric charge. Field strength. Potential.
Conductivity. The voltage and current. Metals, semiconductors, dielectrics.
A magnetic field. Magnetic field strength, the magnetic induction, the magnetization.
Maxwell's equations
Interference and Diffraction. Huygens-Fresnel principle. Fresnel and Fraunhofer Diffraction.

Section 2. Thermodynamics and Kinetics

Thermodynamic system and thermodynamic functions. The laws of thermodynamics. The evolution of systems and balance.
Phase Equilibrium in one-component and two-component systems.
Surface. Adsorption and surface tension.
The chemical reaction rate.

Section 3. Properties of solids.

The interactions between particles in solids.
Mass transfer. Diffusion in Solids.
The crystal structure of solids.
Methods of studying the structure of solids. X-ray, electron microscopy.
Physical methods of determining the composition of solids. Spectroscopy.
Spectral and electron microprobe analysis.mena in electrolytes and ionic crystals.

Section 4. Mechanics and elasticity theory

Principle of least action. Lagrange function. Lagrange equation.
Energy, momentum and angular momentum conservation laws.
Tensor of deformations. Stress tensor. Hooke's law.
Elastic waves in isotropic medium.

Section 5. Quantum mechanics

De Broglie's waves. Uncertainty principle. Superposition principle and wave packets.
Schrödinger's equation. Particle in potential well. Propagation of particle through potential barrier: tunneling effect.
Structure of atoms. Hydrogen atom. Motion in central symmetrical field.
Bohr-Sommerfeld quasi classical quantization rule.
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,
2. 3rd edition (Elsevier, 1980, reprinted in 2005).
3. L.D. Landau E.M. Lifshitz, Course of Theoretical Physics. Volume 7: Theory of Elasticity, 3rd edition (Elsevier, 1980, reprinted in 2005).
4. L.D. Landau E.M. Lifshitz, Course of Theoretical Physics. Volume 3: Quantum mechanics, 3rd edition Elsevier, 1980, reprinted in 2005.
5. 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)
6. 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. Helmholz, 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; 4th 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.