PROGRAM
Entrance Examination
"Physics"

Master's program
"Quantum Physics for Advanced Materials Engineering"

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 in "Quantum Physics for Advanced Materials Engineering".

Entrance examinations are held in the form of an interview with use of remote technologies.

The duration of the entrance examination is not to exceed 40 minutes.

The maximum score is 100 points and is the combined sum of the scores from the results of the interview component and the score for individual achievement.

The maximum amount of points for the interview component is 60 points. Two questions derived from program content comprise the interview component. Each question is scored from 0 to 20 points. Additionally, the level of knowledge of professional terminology in English is being evaluated from 0 to 20 points. The results of the evaluation interview are the sum of points earned for each question and for the level of knowledge of professional terminology demonstrated in English.

The maximum amount of points for the individual achievement component is 40 points and consists of assessing the following achievements: academic achievement (cumulative grade point average from previous post-secondary institutions of higher education, publications, participation in conferences, scientific achievements, achievements in educational and social activities (certificates, diplomas, etc.) from 0 to 20 points; Statement of Purpose from 0 to 10 points; and letter(s) of recommendation from 0 to 10 points total.

Candidate must earn a minimum of 20 points to be considered eligible for admission.

II. Examination Content Outline

Classical Mechanics

1. Fundamental principles of classical mechanics
   1.1. Fundamental problems of classical mechanics. Generalized coordinates and momenta.
   1.2. The principle of least action. Lagrangian function. Euler-Lagrange equation and the equations of motion.
   1.3. Galilean relativity principle. Symmetries of space and time, and integrals of motion. Conservation laws of energy, momentum and angular momentum.

2. Integration of equations of motion
   2.1. The motion of a particle in a one-dimensional potential field.
   2.2. Motion of a particle in a central-force field.

3. Small oscillations
   3.1. Free one-dimensional oscillations.
   3.2. Forced oscillations, damped oscillations, and forced oscillations under friction.
   3.3. Oscillations of systems with multiple degrees of freedom.

4. The Hamiltonian method in classical mechanics
   4.1. The Hamiltonian equations of motion.
   4.2. Canonical transformations in classical mechanics.
   4.3. The Poisson bracket and constants of motion.

Quantum mechanics

1. Postulates of quantum mechanics
   1.1. Rudimentary functional analysis 1. Scalar product, bra and ket.
   1.2. Rudimentary functional analysis 2. Linear operators.
   1.3. Postulates of quantum mechanics.

2. 1D Schroedinger equation
   2.1. Analogy between optics and quantum mechanics. Fermat principle in optics
   2.2. Heuristic *derivation* of Schroedinger equation. Commutators and conservation laws.
   2.3. Schrodeinger and Heisenberg description.
   2.4. Properties of 1D Schroedinger equation. Free particle. Normalization.

3. Angular momentum
   3.1. Definition of angular momentum operator. Its eigenvalues.
   3.2. Spherical functions.
   3.3. Cases of simple addition of angular momentum.

4. 3D Schroedinger equation
   4.1. Separation of variables in systems with axial and spherical symmetry.
   4.2. Exact solutions: hydrogen atom, 3D oscillator, degeneracy.

III. Recommended Reading

Classical Mechanics

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).

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.

Problems and solutions

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

Quantum mechanics

1. L.D. Landau E.M. Lifshitz, Course of Theoretical Physics. Volume 3: Quantum mechanics, 3rd edition Elsevier, 1980, reprinted in 2005.
2. 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)
3. Claude Cohen-Tannoudji , Bernard Diu Frank Laloe, Quantum mechanics. John Wiley and Sons, Inc./Hermann (1977).

Additional Reading

1. P.A.M. Dirac The Principles of Quantum Mechanics, Oxford University Press, USA; 4 edition (February 4, 1982)
2. R.P. Feynman, R.B. Leighton, M. Sands , The Feynman Lectures on Physics, 2nd Revised edition, Addison Wesley, vol. 8-9, 2005.