AL-FARABI KAZAKH NATIONAL UNIVERSITY

Approved at the meeting of the
Scientific and methodological Council
of Al-Farabi KazNU
Protocol № 6
from «22» June 2020 y.
Vice-rector on Accademic Affairs
________________А. К. Khikmetov

PROGRAM OF ENTRANCE EXAM FOR APPLICANTS TO PhD IN THE EDUCATIONAL PROGRAM «8D05306 – PHYSICS»

ALMATY 2020

The program is developed in accordance with the State educational standard on the educational program «8D05306 – Physics» by F. B. Belissarova, candidate of science in Physics and Mathematics, acting Professor.

The program considered at the meeting of the Department of theoretical and nuclear physics

Protocol № 41 from «16» June 2020 y.

Head of the Department ___________________ **M.E. Abishev**

Approved at the meeting of Methodological Bureau of faculty Physics And Technology

Protocol № ______ from «_____»________2020 y.

The Chairwoman of the Methodological Bureau ___________ **A.T. Gabdullina**

Approved at the meeting of the Academic Council

Protocol № ______ from «_____»________2020 y.

Chairman of the scientific Council,

Dean of the faculty ____________________ **A.E. Davletov**

Scientific Secretary ____________________ **R.U. Masheyeva**

CONTENT

1. Goals and tasks of the entrance in the educational program "8D05306 - Physics"

The entrance exam is designed to determine the practical and theoretical training of the applicant and is conducted to determine compliance of knowledge, abilities and skills of the applicant with the requirements of doctoral studies by field of study.

"Form of entrance examination – written exam. Examinees record their answers to questions of examination on the answer sheet. On appeal, the basis for consideration are the written entries in the answer sheet".

2. Requirements to level of preparation of applicants to PhD

The previous minimum level of education of persons wishing to assimilate the educational program of doctoral studies in the EP "6D060400-Physics":

- 6M060400-Physics
- 6M060500-Nuclear physics
- 6M011000 Physics (education)
- 6M072300-Technical physics
- 6M061100-Physics and astronomy

Admission requirements:

have to:

- *to be able to* navigate freely in fundamental and applied questions of physics, which in the framework of the educational program of a magistracy is carried out of the relevant specialization;
- *to have an idea* about the latest achievements of science and technology;
- *know* modern experimental, theoretical and numerical methods of research of physical phenomena and processes; actual problems of physics.

3. Prerequisites educational programs

1. OPSF 5301 - Basic principles of modern physics - 2 credit.
2. VKTP5206 - Introduction to quantum field theory - 3 credit.
3. KMMS5207 - Computer simulation of many-body systems - 3 credit.

4. List of examination topics

Discipline «*Basic principles of modern physics*»

1. Basic principles of modern physics. Principle of relativity. Galilean and Lorentz transformations. Equations of physics in covariant form.
2. Principles of symmetry, superposition, uncertainty. Principle of correspondence as an orientation when constructing of new physical theories.
3. Principle of symmetry and conservation laws. Energy conservation law and time homogeneity. Impulse and momentum conservation law as a consequence of translational invariance and isotropy of space. Mirror symmetry of space and parity conservation law.
4. Principle of in distinguishability of identical particles in quantum mechanics and particles statistics. Charge independence of strong interactions.
5. Additive conservation laws as a consequence of invariance with respect to gauge transformations: electric charge, baryonic and lepton number. Symmetry and levels' degeneracy order. Operator of symmetry and unitary transformations. Application of uncertainty principle in physical problems.
6. Use of relativistic invariance (invariant mass) when describing the processes at high energies in the micro world. Connection of particles energies in laboratory system and system of mass center. Particles beams accelerators – synchrotrons and colliders. Large hadron Collider.

7. Measurement of mass of unstable elementary particles. Thresholds of nuclear processes. Short-living particles-resonances. Lifetime of fast moving elementary particles. Conception of virtual particles and processes.

List of recommended literature

Basic:

1. Грушевицкая Т.Г., Садохин А.П. Концепции современного естествознания. М. – 2003. Юнити-Дана. 670 с.
2. Фрауэнфельдер Ф., Хенли Э. Субатомная физика «Мир», Москва, 1979 г., 730 с.
3. Рейдер Л., Элементарные частицы и симметрии «Наука», Москва, 1983 г., 317 с.
4. М.А. Жусупов, С.К. Сахиев, Р.С. Кабатаева. Квантовая теория рассеяния, Астана, 2012 г., 206 с.
5. Жусупов М.А., Юшков А.В. Начала физики. Том 1. Алматы, 2006. 464 с.

Additional:

1. Фаустов Р.Н., Шелест В.П. Квантовая метрология и фундаментальные константы. Москва, Мир, 1981. 368 с.
2. П.А.М. Дирак, Релятивистское уравнение электрона. Успехи физических наук, том 129, вып.1, стр.681-691; Воспоминания о необычайной эпохе УФН, том 153, вып.1, стр.105-134.
3. Д.Мехра. Золотой век теоретической физики, УФН, том 153, вып.1, стр.135-172.
4. Общие сведения об античастицах. Л.Валантэн. Субатомная физика: ядра и частицы, М., «Мир»,1986, с. 83-94.
5. Давыдов А.С. Квантовая механика. Физико-математическая литература,. М., 1973, 611 стр.
6. Валантэн Л. и др. Субатомная физика: ядра и частицы, том 1 и 2, «Мир», М., 1986.272 стр. в 1 томе и 330 стр. во 2 томе.
7. Варшалович Л. и др. Квантовая теория углового момента. М. Высшая школа. 1981.
8. Жусупов М.А., Юшков А.В. Физика элементарных частиц. Алматы 2006, 488 с.
9. Сб. Фундаментальная структура материи, под редакцией Дж. Малви, Москва, Мир, 1984, 311 с.
1. Л.В.Тарасов. Основы квантовой механики, Москва, Высшая школа, 1978, 287 с.
2. Дж.Эллиот, П.Добер. Симметрии в физике, том 1, 368 с., том 2, 416 с. Москва, Мир, 1983.

Discipline «Introduction to quantum field theory»

1. Classical fields theory. Lagrange formalism. Fields and particles. Hamilton and Lagrange formalisms. Lagrange function and principle of stationary action. Transformational properties of field function. Tensors and spinors.
2. Scalar field. Klein-Gordon equation. Lagrange formalism of real scalar field. Impulse representation and frequency components. Discrete representation. Complex scalar field. Pion field. Notation of Klein-Gordon equation in a form of a system of first order equations.
3. Electromagnetic field. Potential of electromagnetic field. Gradients transformation and Lorentz condition. Lagrange formalism. Cross, dilatational and time components. Spin.
4. Quantization of free fields. General principles of quantization.
5. Operator nature of field functions and state amplitude. Representations of Schrodinger equations. Transformational properties of state amplitude and field operators. Postulate of wave fields quantization. Physical meaning of positive and negative frequency components and conjugated functions. Vacuum state and state amplitude in Fock' representation.
6. Permutation relations. Types of permutation relations. Fermi-Dirac and Bose-Einstein permutation relations. Connection of spin and statistics. Pauli theorem. Normal product of

operators and notation of dynamical variables. Permutation relations in discrete impulse representation.

7. Quantization of scalar, vector fields. Real and complex scalar fields. Pi-meson fields. Complex vector field. Hamilton formalism and canonical quantization.

8. Quantization of electromagnetic and spinor fields. Peculiarities of electromagnetic field and quantization scheme. Indefinite metric. Notation of fundamental quantities. Quantization by Fermi-Dirac and permutation functions. Dynamical variables. Charge conjugation. Quantized neutrino's field.

9. Fundamentals of theory of interacting fields. S-matrix. S-matrix in interaction representation. Green's functions. Reduction formula. Feynman rule for S-matrix. Calculation of matrix elements. Cross section of particles scattering. Some interaction models.

10. Open the chronological products. Chronological coupling. Vick' theorem for chronological products.

11. Examples of second order processes calculation. Compton scattering. Annihilation of electron-positron pair. Braking radiation.

12. Compton scattering. Cross section of photon scattering on free electron. Differential effective cross section. Matrix elements. Klein-Nishina-Tamm formula.

13. Conception of divergence elimination from S-matrix. Divergences of S-matrix in electrodynamics. Diverging diagram with two outer electron lines Σ. Separation of diverging part from Σ. Diverging diagram with two outer photonic lines Π. Separation from Π and gradient invariance. Construction of integrable function S_2.

14. Annihilation of electron-positron pair into photons. Simplest diagram, corresponding to process of electron and positron annihilation. Description of two-photon annihilation on diagram. Values of energies for electron and positron. Construction of matrix elements by correspondence principle. Differential effective cross section of electron-positron pair annihilation.

15. Bogolubov's method. Conservation laws and entropy increase law. Continuity equation in Γ-space. Continuity equation for density. Impulse variation law. Law of gas kinetic energy variation.

List of recommended literature

Basic:

1. David Tong, Quantum Field Theory, Department of Applied Mathematics and Theoretical Physics, Centre for Mathematical Sciences, Wilberforce Road, Cambridge, CB3 OWA, UK http://www.damtp.cam.ac.uk/user/tong/qft.html.

2. Warren Siegel, FIELDS, C. N. Yang Institute for Theoretical Physics, State University of New York at Stony Brook, Stony Brook, New York 11794-3840, USA, http://insti.physics.sunysb.edu/~siegel/plan.html.

Additional:

1. ERNEST M. HENLEY, WALTER THIRRING, ELEMENTARY QUANTUM FIELD THEORY, McGRAW-HILL BOOK COMPANY, INC.

2. Bo Thide, Electromagnetic field theory, http://www.plasma.uu.se/CED/Book.

3. Luis Alvarez-Gaum´ea,and Miguel A. Vazquez-Mozo, Introductory Lectures on Quantum Field Theory, Physics Department, Theory Division, CERN, CH-1211 Geneva 23, Switzerland, arXiv:hep-th/0510040v4.

Discipline "Computer modeling of many- particle systems"

1. Subject and tasks of the discipline. A brief review of known numerical methods for solving problems in the physics of many-particle systems.
2. One particle approximation of the description of many-particle systems. Numerical solution of differential equations. The Cauchy problem.

3. Interaction of particles of many-particle systems. Interaction potentials. Method of pseudopotentials. Method of molecular dynamics. Requirements for the model of the molecular dynamics method. Method of molecular dynamics for a microcanonical ensemble (NVE). Assignment of the initial state of the particle system
4. Classical statistical description of gas and plasma. The Metropolis scheme and periodic boundary conditions. Numerical schemes (the Riemann, Verle, Biman algorithm).
5. The Monte Carlo method. General scheme of application of the Monte Carlo method. The Monte Carlo method for canonical ensemble and its relation to the theory of probability. Algorithm of the Monte Carlo method.
6. Method of molecular dynamics. Requirements for the model of the molecular dynamics method. Method of molecular dynamics for a microcanonical ensemble (NVE). Assignment of the initial state of a particle system.
7. Calculation of autocorrelation functions (AF). Relationship between AF and transfer coefficients. The theory of linear response.
8. Kinetic description of many-particle systems. Solution of differential equations by the methods of Euler, Runge-Kutt.

List of recommended literature

Basic:
1. Baimbetov F.B., Ramazanov T.S. Mathematical modeling in physics of nonideal plasma. - Almaty. Gylym, 1994. - 212 p.
2. Tsvetkov I.V. Application of numerical methods for modeling processes in plasma: a manual. Moscow: MEPhI, 2007. 84 p.

Additional:
1. Akanayev B.A. Numerical methods and automation of the experiment in solid state physics. Almaty, 1998.
2. Govorukhin V., Tsibulin V., Computer in mathematical research. Training course. St. Petersburg. Peter 2001

Evaluation criteria of entrance examination for admission to the PhD course in the EP "8D05306-Physics"

Characteristics of student work	The range of rating points	Evaluation of ECTS	Traditional (4-level) scale of evaluation.
"Excellent" – given a full, detailed answer to a theoretical question. The entrant detects a true understanding of the essence of physical phenomena that determine the physical quantities, derivation of the necessary relations, performs correctly drawings, diagrams and graphs associated with the response. The applicant shows creative ability in the analysis and evaluation of theoretical material, shows the ideological representation (the material world and its knowability, the unity and interrelation of events).	95-100	A	Excellent
	90-94	A-	
"Good" – given a full, but not a consistent answer to the question, but shows the ability to allocate the main thing. Allowed 1-2 errors in the disclosure of concepts, definitions, laws, records, formulas, and measurements, which the applicant finds it difficult to fix yourself.	85-89	B+	Good
	80-84	B	
	75-79	B-	
	70-74	C+	
"Satisfactorily" – given the insufficient and insufficiently detailed answer. The logic and sequence of presentation have violations. Mistakes in discovering concepts, laws, phenomena, the translation values in SI. Carelessly made drawings, diagrams, records, there are no signs of projection or vectors.	65-69	C	Satisfactorily
	60-64	C-	
"Satisfactorily" – given a partial answer, logic and consistency have significant errors. The inaccuracy of charts, diagrams, wording, omitted the names of units of measure, incorrect marking; allowed grammatical errors in the physical terms, there are no signs of projection or vectors.	55-59	D+	Satisfactorily
	50-54	D	
"Unsatisfactorily" (no retest policy) – applicant provides an answer to the question without understanding the relationships between elements. Fragmentary: making mistakes - do not know the formulas or do not know how to operate them. Not able to convert quantities from SI.	0-49	F	Unsatisfactorily