Final exam program

on discipline **"Introduction to the nucleus theory"** for 4^{th} course students

for specialty "5B060400 –Physics"

The proposed program for the discipline **"Introduction to the nucleus theory"** is made according to the discipline's syllabus. The program determines the requirements for the levels of mastering the academic discipline, to which the student should be capable of learning: demonstrate acquired knowledge (specifically) and it's understanding; demonstrate an understanding of the overall structure of the study field and the relations between its elements (specifically); include new knowledge in the context of basic knowledge, interpret its contents; constructive educational and social interaction and cooperation in the group; propose to consider a problem, to reason its importance; accept criticism and to criticize; work in a team; recognize the role of taken course in the implementation of individual learning paths. The system of descriptor verbs must be used during the formation of competences; active and interactive methods is recommended to ensure deeper understanding and learning of educational material and to achieve learning outcomes of the course.

The aim of the course: learning the modern physics of atom nucleus and quantum mechanics of many-particle systems..

At the exam, students will be asked two theoretical questions (33 points each) and one practical question 34 point).

Exam questions:

1.	Give definition and describe the interactions relate to fundamental.	Lecture № 1
2.	List the fundamental interactions in ascending order of the relative intensity.	Lecture № 1
3.	Describe the gravitational waves and the possible sources of their nature.	Lecture № 2
4.	Explain in which physical phenomena is weak interactions occur.	Lecture № 2
5.	Describe weak interactions and explain why they are considered as short-action.	Lecture № 2
6.	Describe the values of the interaction energy which can be talked about merger of weak and electromagnetic interactions.	Lecture № 3
7.	Describe pions and gluons are two kinds of quanta in the strong interaction.	Lecture № 4
8.	Describe an importance of neutrinos on thermonuclear processes inside the Sun and stars.	Lecture № 4
9.	Describe the registration of neutrinos.	Lecture № 5
10.	Give definition and describe neutrino oscillations.	Lecture № 5
11.	Describe what changes have been the concept of "rest mass" and "relativistic mass" in recent developments in particle physics.	Lecture № 5
12.	Explain the meant of the terms "technology" and "quantum" sensitivity limits in the physical experiment.	Lecture № 5
13.	Explain "Colored" and "colorless" particles.	Lecture № 5
14.	Give definition and describe the cumulative particle.	Lecture № 5
15.	Explain the concept of "mass defect" and how they define the "valley of stability".	Lecture № 6
16.	Explain four groups which are divided presently known radioactive processes.	Lecture № 6
17.	Characterize the model of "liquid drop" which explains nuclear fission.	Lecture № 6
18.	Give definition and describe which nuclei characterized proton and double-proton radioactivity.	Lecture № 7
19.	Explain a cluster radioactivity.	Lecture № 7
20.	Explain beams of accelerated radioactive nuclei which are used to obtain and study of exotic isotopes.	Lecture № 7
21.	Specify the main features and characteristics of the interactions of charged particles.	Lecture № 7
22.	Specify the main features of the strong interaction.	Lecture № 4
23.	Describe the basic characteristics of the weak interaction.	Lecture № 2
24.	Describe the particles or field which creates interaction.	Lecture № 1

25.	Describe the particles that are elementary components of matter.	Lecture № 8
26.	Explain the meaning of quantum number "color" for quark.	Lecture № 5
27.	Describe the difference of "gluons" and quarks.	Lecture № 8
28.	Explain the meaning and describe Feynman diagrams.	Lecture № 15
29.	Give definition and describe Planck's constant.	Lecture № 8
30.	Explain the physical meaning of indeterminacy.	Lecture № 9
31.	Explain what an important role plays weak interaction in the formation of our Universe.	Lecture № 10
32.	Explain why do we need high-energy particle accelerators and why they can be used to understand the physics of the early Universe.	Lecture № 9
33.	Describe the Large Hadron Collider.	Lecture № 9
34.	Describe a cyclotron and the basic principles of its operation.	Lecture № 9
35.	Give definition and describe Yukawa potential and the Coulomb potential - describe their main characteristics and differences.	Lecture № 10
36.	Give definition and describe leptons. Give the types of leptons and their characteristics.	Lecture № 10
37.	Give definition and describe spins of elementary particles.	Lecture № 10
38.	Give definition and describe Pauli principle and structure of nuclei. Describe the construction of the electron orbits in atoms.	Lecture № 10
39.	Describe Fermi and Bose particles.	Lecture № 11
40.	Give examples of the properties of particles associated with quantum number "strangeness".	Lecture № 11
41.	Describe the binding energy of the nuclei.	Lecture № 10
42.	Explain how to determine the binding energy of the nucleus, knowing the mass of the nucleus, the mass of the proton and neutron.	Lecture № 10
43.	Find a specific energy of a nucleus of a helium atom.	Lecture № 11
44.	Determine the total binding energy of a nucleus of uranium-238.	Lecture № 12
45.	Determine the total specific binding energy of a nucleus of molybdenum-96.	Lecture № 12
46.	Determine the total binding energy of a nucleus of osmium -191.	Lecture № 12
47.	Describe the types of radioactivity of different nuclei.	Lecture № 12
48.	Describe the reaction of the alpha decay of nuclei.	Lecture № 13
49.	Describe the reaction of the beta decay of nuclei.	Lecture № 13
50.	Describe reaction of electron capture.	Lecture № 13
51.	Give definition and describe gamma and beta radiation of nuclei.	Lecture № 13
52.	Analyze the reaction of spontaneous fission of heavy nuclei. Describe the fission products.	Lecture № 13
53.	Explain principle of operation of nuclear reactors based on uranium fission.	Lecture № 13
54.	Describe fission chain reaction.	Lecture № 13
55.	Analyze the reaction of light nuclei. Write the fusion reaction of protons with form of deuterium nuclei.	Lecture № 14
56.	Give definition and describe burning the nuclei of hydrogen atoms on the Sun.	Lecture № 14
57.	Give definition and describe cycles of thermonuclear burning of hydrogen with form of helium nuclei.	Lecture № 14
58.	Explain what means "island of stability" for the nuclei of chemical elements.	Lecture № 11
59.	Characterize properties of nuclei far from island of stability. Give examples.	Lecture № 15
60.	Explain abundances of chemical elements in nature.	Lecture № 15

Evaluation and attestation policy

Criteria-based evaluation:

Assessment of learning outcomes in correlation withdescriptors (verification of competence formation during midterm control andexaminations).

Summative evaluation:

evaluation of the presence and activity of the work in the classroom; assessment of the assignment, independent work of students, (project/casestudy/ program/...)

The formula for calculating the final grade.

$$\text{Final grade for the discipline} = \frac{\text{IC1} + \text{IC2}}{2} \cdot 0{,}6 + 0{,}1\text{MT} + 0{,}3\text{FC}$$

Below are the minimum estimates in percentage terms:

95% - 100%: A	90% - 94%: A-	85 % - 89%: B
80% - 84%: B	75% - 79%: B-	70% - 74%: C+
65% - 69%: C	60% - 64%: C-	55% - 59%: D+
50% - 54%: D-	0% -49%: F	

LITERATURES

1. Bethe H.A., Morrison P. Elementary Nuclear Theory, 1st ed. New York: Wiley, 1947. 147 p.
2. Heyde K. Basic Ideas and Concepts in Nuclear Physics: An Introductory Approach, 2nd Edition. Institute of Physics Publishing Bristol and Philadelphia, 1999. 547 p.
3. Kamal A. Nuclear Physics, Springer, 2014. — 612 p. — (Graduate Texts in Physics).
4. Iliadis Ch. Nuclear Physics of Stars, WILEY-VCH Verlag, Weinheim, 2007, 666 pages Martin B.R. Nuclear and Particle Physics: An Introduction, Wiley, 2006. — 415 p.
5. Takigawa N., Washiyama K., Fundamentals of Nuclear Physics, Springer, Japan, 2017. – 277 p.
6. Shultis J.K., Faw R.E. Fundamentals of Nuclear Science and Engineering, Kansas State University Manhattan, Marcel Dekker, New York, Basel, 2002, 506 pp.
7. Frobrich P., Lipperheide R., Theory of nuclear reactions, Clarendon Press, Oxford. 1996 - 476 p.
8. J.M.Blatt and V.F.Weisskopf, Theoretical Nuclear Physics, Springer, 1979, VII.5 9. Nuclear Physics by Irving Kaplan 2nd edition1962 Addison-Wesley