Final exam program

on discipline **"Nuclear astrophysics"** for 1st course master students of specialty "6M060400 – Physics"

The proposed program for the discipline **"Nuclear astrophysics"** 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: describe acquired knowledge (specifically) and it's understanding; interpret an understanding of the overall structure of the study field and the relations between its elements (specifically); generalize new knowledge in the context of basic knowledge, interpret its contents; create educational and social interaction and cooperation in the group; explain the solution of the problem, its importance; classify criticism and to criticize; decide to work in a team; combine 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; design active and interactive methods which are recommended to ensure deeper understanding and learning of educational material and to achieve learning outcomes of the course.

The aim of the course: to give the students the deep understanding of the modern physics of nucleus of atoms and quantum mechanics of many-particle systems and self-study

At the exam, students will be asked three theoretical questions (the first two are 33 points each and the third are 34 points each).

Exam questions:

1.	Give definition and describe the complete density of energy and energy falling on one baryon in terms of concentration of baryons	Lecture № 1
2.	Describe the expression for a quantity of heat received in terms of one baryon	Lecture № 1
3.	Give definition of an equilibrium condition in an element of Wednesday through warmth and entropy, falling on one baryon	Lecture № 2
4.	Explain the first law of thermodynamics through the energy falling on one baryon, and concentration of baryons	Lecture № 2
5.	Give values for weight and the radius of the Sun; the reference values for masses and the sizes of neutron stars, white dwarfs and black holes in mass units and the extent of the Sun; the range of values of mass of stars - predecessors of compact stars (in Sun mass units)	Lecture № 2
6.	Describe dependence of warmth of dQ in an element of Wednesday from temperature of T and ds – an entropy on one baryon	Lecture № 3
7.	Explain and write down for an environment element in equilibrium the equation for the energy falling on one baryon depending on pressure, volume (falling on one baryon) and temperature	Lecture № 4
8.	Explain write down for an environment element in equilibrium the equation for the energy falling on one baryon depending on pressure, concentration of particles of a grade of i and their chemical potential, and temperature	Lecture № 4
9.	Describe and write down a differential equation of dependence of pressure and temperature on density of number of baryons	Lecture № 3
10.	Give definition and describe a differential equation of dependence of chemical potential on density of number of particles of a grade of i	Lecture № 3

11.	Characterize write down reactions of an electron capture and to offer an explanation of course of such reactions in superdense environments (crystals)	Lecture № 4
12.	Give definition of a formula for the free energy counting on one baryon	Lecture № 5
13.	Describe Cumulative distribution function of particles in case of Fermi statisticians and in a case to Bosa statisticians	Lecture № 5
14.	Explain relativistic parameter in terms of an impulse of Fermi	Lecture № 5
15.	Characterize density of electrons through Fermi impulse for a degenerate electronic Fermi liquid	Lecture № 6
16.	Express density of electrons of a degenerate electronic Fermi liquid through relativistic parameter	Lecture № 6
17.	Describe expression for pressure of a degenerate electronic Fermi liquid in the form of integral on impulses of electrons.	Lecture № 6
18.	Give values for weight and the radius of the Sun; to give the reference values for masses and the sizes of neutron stars, white dwarfs and black holes in mass units and the extent of the Sun; to give the range of values of mass of stars - predecessors of compact stars (in Sun mass units)	Lecture № 5
19.	Give definition of reactions of an electron capture and to offer an explanation of course of such reactions in superdense environments (crystals)	Lecture № 5
20.	Explain Cumulative distribution function of particles in case of Fermi statisticians and in a case to Bosa statisticians	Lecture № 7
21.	Characterize the expression for substance density through the mass of ions and density of their number	Lecture № 7
22.	Describe substance equation of state in the form of a polytrope in case of nonrelativistic electrons	Lecture № 7
23.	Describe substance equation of state in the form of a polytrope in case of relativistic electrons	Lecture № 7
24.	Describe substance equation of state in the form of a polytrope in case of nonrelativistic neutrons	Lecture № 8
25.	Describe substance equation of state in the form of a polytrope in case of relativistic neutrons	Lecture № 8
26.	Explain the approximate relation of Coulomb energy to thermal energy for an undergenerate gas, to offer an explanation for this relation	Lecture № 8
27.	Give definition and describe the approximate relation of Coulomb energy to thermal energy for degenerate gas, to offer an explanation for this relation	Lecture № 8
28.	Explain the the inverse beta decay (reaction of an electron capture in superdense environments)	Lecture № 9
29.	Describe Compact stars: origin, types and data of astrophysical supervision	Lecture № 9
30.	Give definition of white dwarfs: main characteristics, values of masses, communication of a brightness of stars with their characteristics; internal structure	Lecture № 9
31.	Give definition of white dwarfs: element structure, filing methods, spectral characteristics	Lecture № 9
32.	Give definition of white dwarfs: the reference reactions in a gas envelope and a solid core	Lecture № 8

33.	Describe Black holes: Chandrasekar's limit, methods of filing of black holes	Lecture № 9
34.	Describe neutron stars: versions, methods of supervision	Lecture № 9
35.	Describe neutron stars: pulsars, glitches	Lecture № 8
36.	Describe neutron stars: microstructure pulsar of impulses	Lecture № 8
37.	Analyze double systems: neutron star and routine gas star, substance accretion phenomenon	Lecture № 8
38.	Give definition and describe white dwarfs: the reference reactions in a gas envelope and a solid core	Lecture № 9
39.	Analyze neutron stars: versions, methods of supervision	Lecture № 10
40.	Explain reactions of the inverse beta decay (reaction of an electron capture in superdense environments)	Lecture № 13
41.	Explain double systems: black hole and routine gas star, substance accretion phenomenon	Lecture № 10
42.	Describe double systems: neutron star and white dwarf, methods of filing and data of supervision	Lecture № 10
43.	Give definition of brown dwarfs: main characteristics, methods and data of supervision	Lecture № 11
44.	Explain red dwarfs: main characteristics, methods and data of supervision	Lecture № 11
45.	Characterize types of the main forces: comparative characteristics, intensity and radiuses of action	Lecture № 11
46.	Describe weak couplings – their role in evolution of the Universe and formation of substance	Lecture № 11
47.	Give definition and describe the strong couplings - their role in evolution of the Universe and formation of a matter	Lecture № 12
48.	Describe electromagnetic forces – their role in formation of structures, atoms and molecules	Lecture № 12
49.	Explain the quantum chromodynamics – their role in formation of kernels	Lecture № 12
50.	Describe the strange and quark stars – their main characteristics and properties	Lecture № 13
51.	Analyze the primary stage of evolution of the Universe – a role of the strong and weak forces	Lecture № 13
52.	Explain primary stage of development of the Universe – a role of electromagnetic and gravitational forces in formation of structures	Lecture № 13
53.	Explain relict electromagnetic radiation, data of supervision and theory of the phenomenon	Lecture № 14
54.	Explain relict neutrino radiation, data of supervision and theory of the phenomenon	Lecture № 14
55.	Explain and describe dark matter – data of supervision, the main questions and problems	Lecture № 14
56.	Explain and describe dark energy – data of supervision, problems and assumptions	Lecture № 15
57.	Analyze nuclear reactions in gas stars, basis cycles of reactions	Lecture № 15
58.	Describe primary nucleosynthesis – the main reactions	Lecture № 15
59.	Describe problem of "a lithium failure" in abundance of chemical elements	Lecture № 15
60.	Characterize the theory of a nucleosynthesis – formation of mild and average elements	Lecture № 15

Evaluation and attestation policy

Criteria-based evaluation:

Assessment of learning outcomes in correlation with descriptors (verification of competence formation during midterm control and examinations).

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. Richard N. Boyd. An Introduction to Nuclear Astrophysics. University of Chicago Press (April 15, 2008)
2. Norman K. Glendenning. Compact Stars: Nuclear Physics, Particle Physics, and General Relativity. Springer; 2nd edition (June 16, 2000)
3. D. Perlov, A.Vilenkin Cosmology for the Curious. Springer; 1st ed. 2017 edition. July 20, 2017
4. Gershberg R.E. Active solar-type main sequence stars. Odessa: Astroprint 2002.
5. B.Greene.The Elegant Universe: Superstrings, Hidden Dimensions, and the Quest for the Ultimate Theory Hardcover – October 17, 2003
6. Cotnikova R. T Astrophysics. Irkutsk .: RIO 2005.
7. A.G.W. Cameron and David Miles Kahl.Stellar Evolution, Nuclear Astrophysics, and Nucleogenesis Dover Publications; 2 edition (March 21, 2013) Feb 21, 2013