APPROVED
at a meeting of the Academic Council of NJSC «KazNU named after al-Farabi»
Protocol № 11 from 23. 05. 2025 y.

The program of the entrance exam for applicants to the PhD for the group of educational programs D098 - «Heat power engineering»

I. General provisions

1. The program was drawn up in accordance with the Order of the Minister of Education and Science of the Republic of Kazakhstan dated October 31, 2018 No. 600 «On Approval of the Model Rules for Admission to Education in Educational Organizations Implementing Educational Programs of Higher and Postgraduate Education» (hereinafter referred to as the Model Rules).

2. The entrance exam for doctoral studies consists of writing an essay, an exam in the profile of a group of educational programs and an interview.

Блок	Баллы
1. Interview	30
2. Essay	20
3. Exam according to the profile of the group of the educational program	50
Total admission score	100/75

3.The duration of the entrance exam is 3 hours 10 minutes, during which the applicant writes an essay and answers the electronic examination ticket. The interview is conducted at the university premises before the entrance exam.

II. Procedure for the entrance examination

1. Applicants for doctoral studies in the group of educational programs D098- «Heat power engineering» write a problematic / thematic essay. The volume of the essay is at least 250 words.

The purpose of the essay is to determine the level of analytical and creative abilities, expressed in the ability to build one's own argumentation based on theoretical knowledge, social and personal experience.

Types of essays:

- motivational essay revealing the motivation for research activities;
- scientific-analytical essay justifying the relevance and methodology of the planned research;

- problem/thematic essay reflecting various aspects of scientific knowledge in the subject area.

2. The electronic examination card consists of 3 questions

Topics for exam preparation according to the profile of the group of the educational program:

Discipline: Blowers and Thermal Engines

Topic: Thermal engines. Steam installations. Gas turbine engines. Jet engines. Diesel power stations. Working and thermal diagrams of jet engines. Compressors and compressor installations. Total specific work of a gas turbine engine

Subtopics: Thermal engine cycles; Generalised thermodynamic cycles of thermal engines; Graphical representation of a heat transfer cycle at constant volume; Heat transfer diagram of a gas turbine plant thermal cycle at constant pressure and characteristics of each process; Indicator diagram of a single-stage compressor; Multi-stage compressors. Minimum work of multi-stage compressors; Total internal work of a gas turbine plant; Cavitation during operation of a centrifugal pump. Determining the application of compressors depending on the rotation speed and pressure; T,S diagram of a multi-stage compressor; Thermal diagrams of cycles of combined cycle power plants with a mixed working fluid.

Discipline: Alternative Energy

Topic: Renewable energy sources. Renewable energy resources in Kazakhstan. Problems associated with the use of traditional energy sources.

Subtopics: Renewable energy resources; converter manufacturing technologies; problems of non-traditional energy use; energy conservation using alternative energy sources.

Discipline: Physical Fundamentals of Energy Conservation

Topic: Energy complexes. Energy sectors and development dynamics of the Republic of Kazakhstan. Energy conservation. Energy conservation in heat-generating installations. Energy conservation in thermal technologies Subtopics: Regulatory and legal framework in the Republic of Kazakhstan related to energy conservation. Energy passport of a manufacturing enterprise. Main areas of energy conservation; Basic equations and laws of heat conduction. Differential equation of heat conduction. Convective heat transfer; Basic equations and theorems of thermal similarity. Fundamentals of combustion. Composition of organic fuel; Fundamentals of energy conservation in the electricity supply system. Organisation and technical fundamentals of electricity supply. Measures to ensure electricity production. Fundamentals of electricity conservation in the design and operation of electrical installations. Fundamentals of energy auditing. Basic structure of an energy audit.

Discipline: ‘Flow of viscous fluids’

Topics: Basic concepts of viscous fluid dynamics. Basic equations of viscous fluid mechanics. Incompressible fluid flow with constant properties. Energy equation. Steady fluid motion. Divergent form of the energy equation. Layered flows. Boundary layer. Automodel transformations of boundary layer equations. Experimental methods for studying viscous fluid flows. Physical experiment tools and methods. Flat free jet (submerged).

Subtopics: Ideal and viscous fluid. Viscosity. Laminar and turbulent flow. Reynolds number. Continuity of the medium. Knudsen number. Compressibility of the medium. Mach number. Law of conservation of substance. Navier-Stokes equations. Continuity equation. Equations of motion. Viscous stress tensor. Translational motion. Rotational motion. Translational-rotational motion. Law of conservation of momentum for an incompressible fluid with constant properties. Energy flux density. Poiseuille flow (dynamic and thermal problem). Cueveta's plane flow (dynamic and thermal problem). Dynamic boundary layer. Properties of the dynamic boundary layer. Boundary layer thickness. Boundary layer equations. Prandtl method. Mises method. Approximate methods for solving the Blasius problem. Displacement thickness. The thickness of the impulse loss. Iteration method.

Discipline: Plasma Technology in Thermal Power Engineering

Topics: Current state of the problem of combustion and processing of energy coals. Methods for improving fuel efficiency. Theoretical and experimental methods for studying plasma processes of ignition, thermochemical preparation, combustion and gasification of coals. Allo-autothermal nature of the conversion of two-phase fuel flows. Physicochemical characteristics of the solid fuels studied. Method for determining the amount of oxidiser required for fuel gasification. Method for calculating the specific energy consumption of the fuel gasification process. Various options for using plasma gasification of solid fuels. Schematic diagrams of plasmatrons. Energy efficiency of the process of electrothermochemical preparation of energy coals for combustion. Methods of burning organic fuel: combustion of solid fuel. Schemes for the organisation of solid fuel combustion.

Subtopics: Main energy sources for heat-generating installations. Classification of organic fuels. Analysis of fuel properties. Classification of solid fuels. Coal grades. Size classes of sorted hard coal. Symbols. Thermodynamic calculation for plasma ignition and combustion of pulverised coal fuel. Classification of liquid fuel. Fuel oil. Fuel oil characteristics. Cracking. Relative density. Conditional viscosity. Flash point. Pour point. Classification of gaseous fuel. Dry gases. Natural gases. Artificial gases. Gasification of solid fuel. Water gas. Heavy hydrocarbons. OFA technology. Method of selective non-catalytic reduction of nitrogen oxides. ‘Sharp’ blast.

Discipline: Numerical Methods in Thermal Power Engineering

Topics: Classification of differential equations. Finite difference methods (basic concept). Basic concepts and notation of the theory of difference schemes. Methods for representing differential equations in finite differences. Methods for investigating the stability and convergence of finite difference schemes. Explicit and implicit schemes.

Subtopics: Approximation of first, second, and mixed derivatives. Taylor series expansion. Polynomial approximation. Integral method. Control volume integration method. Small perturbation method. Von Neumann method. Practical stability method. Algorithm for calculation using an explicit scheme. Examples of explicit schemes. Approximation or scheme viscosity. Principle of splitting by physical processes. Combined schemes. Algorithm for calculating the wave equation. Heat conduction equations using implicit schemes: Crank-Nicholson, DuFort-Frankel with various boundary conditions.

Discipline: "Computer Modelling of Reactive Flows in Combustion Chambers"

Topics: Basic concepts of modelling reactive flows in combustion chambers. Properties of numerical solution methods (consistency, stability, convergence, conservation, boundedness, feasibility, accuracy). Introduction to spectral methods (basic concept). Finite volume methods. Approximation of surface integrals. Approximation of volume integrals. Finite volume methods: approximation of initial terms. Three-dimensional grids. Block-structured grids. Unstructured grids. Finite volume methods: approximation of initial terms. Three-dimensional grids. Block-structured grids. Unstructured grids. Finite volume methods: approximation of initial terms. Three-dimensional grids. Block-structured grids. Unstructured grids. Finite volume methods: approximation of initial terms. Three-dimensional grids. Block-structured grids. Unstructured grids. Finite volume methods: approximation of initial terms. Three-dimensional grids. Block-structured grids. Unstructured grids. Finite volume methods: approximation of initial terms. Three-dimensional grids. Finite volume methods: approximation of source terms. Three-dimensional grids. Block-structured grids. Unstructured grids. Finite element methods based on control volume. Pressure correction equation. Axisymmetric problems. Nonlinear equations and their solution. Newtonian techniques. Improving efficiency and accuracy. Error analysis and evaluation. Error description. Error evaluation. Solution of Navier-Stokes equations. Discretisation of convective and viscous terms. Discreteness of pressure and body force terms. Conservation properties. Choice of variable grid spacing. Pressure calculation. Boundary conditions for Navier-Stokes equations. Introduction to turbulent flows. Direct numerical simulation (DNS). Large eddy simulation (LES). RANS models. Very large eddy simulation. Heat and mass transfer. Flows with variable fluid properties. Free surface flows. Multiphase flows. Ignition.

Subtopics: Grid selection. Step-by-step approximation with regular grids. Overlapping grids. Non-orthogonal grids with boundary approximations. Grid

generation. Selection of velocity components. Grid-oriented velocity components. Cartesian velocity components. Boundary condition satisfaction. System of algebraic equations. Discretisation errors. Approximation of convective and diffusive flows. Interpolation and differentiation practices (Upwind Interpolation (UDS), Linear Interpolation (CDS), Quadratic Upwind Interpolation (QUICK), higher-order schemes). Introduction to solving systems of linear equations. Direct methods (Gauss elimination, LU decomposition, tridiagonal systems, cyclic reduction). Introduction to solving systems of linear equations. Iterative methods (basic concept, convergence, some basic methods, incomplete LU decomposition: Stone's method, AD1 and other splitting methods, conjugate gradient methods, double conjugate gradients and CGSTAB, multigrid methods). Parallel computing in CFD. Iterative schemes for linear equations. Domain decomposition in space. Domain decomposition in time. Efficiency of parallel computing. Compressible flow. Pressure correction methods for arbitrary Mach numbers. Methods developed for compressible flow.

Discipline: Fundamentals of thermal conductivity Theory

Topics: thermal conductivity in solids. Mathematical description of the thermal conductivity process. Thermal conductivity in steady state. Unsteady thermal conductivity. Regular cooling (heating) of bodies. Convective heat transfer in a homogeneous medium. Differential equations of convective heat transfer. Similarity theory of convective heat transfer. Fundamentals of laminar boundary layer theory. Fundamentals of turbulent boundary layer theory. Heat and mass transfer during phase transition and chemical transformations. Heat transfer during liquid boiling. Radiative heat transfer.

Subtopics: Heat transfer through walls of various geometric shapes. Ways to intensify heat transfer. Steady-state heat conduction with a heat source. Steady-state heat conduction in multilayer walls of various shapes. Cooling (heating) of an unlimited plate (cylinder, sphere). Cooling (heating) of bodies of finite dimensions. Approximate methods for solving heat conduction problems. Reducing differential equations of convective heat transfer to a dimensionless form. Similarity criteria. Criterion equations. Heat transfer during forced flow around a plate. Heat transfer during free convection. Heat transfer in pipes during forced fluid flow and the peculiarities of heat transfer in this case. Heat transfer in laminar, turbulent and transitional fluid flow regimes in a pipe. Thermal calculation of heat exchangers. Fundamentals of thermal radiation theory. Basic laws of thermal radiation. Methods for investigating radiative heat transfer processes. Geometric characteristics of a system of radiating bodies and properties of radiative fluxes. Heat exchange by radiation between heat and the shell. Radiative heat exchange between two plane-parallel surfaces. Radiative heat exchange between grey bodies with high absorption coefficients. The effect of heat shields. Determination of angular irradiance coefficients by the furnace algebra method.

III. List of references

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