

SCIENTIFIC WORK ON THE TOPIC OF MASTER'S THESIS. PART 2

Educational component work program (Syllabus)

Educational component details

Level of higher education	<i>Second (Master's)</i>
Branch of knowledge	<i>G - Engineering, Manufacturing and Construction</i>
Speciality	<i>G9 "Applied Mechanics"</i>
Educational program	<i>Educational and Scientific Program Engineering of packaging products, processes and equipment</i>
Status of educational component	<i>Mandatory</i>
Form of training	<i>full-time / day</i>
Year of preparation, semester	<i>1 course, spring semester</i>
Volume of educational component	<i>4 (120)</i>
Semester control/ control measures	<i>Test</i>
Schedule of classes	
Language of instruction	<i>Ukrainian</i>
Information about the course leader / teachers	Lecturer: – https://cpsm.kpi.ua/karvatskij-anton-yanovich.html Practical: https://cpsm.kpi.ua/karvatskij-anton-yanovich.html Laboratory: –
Course placement	<i>Link to remote resource Google classroom, https://cpsm.kpi.ua/navchannya/sylabusy/sylabusy-2025-roku.htm</i>

Educational component program

1. Description of the educational component, its purpose, subject of study and learning results

Academic educational component "Scientific work on the topic of the master's thesis. Part 2" includes such important for the preparation of a master's thesis in applied mechanics areas of research as: theoretical foundations for the development of measures to improve energy efficiency, strength and durability of equipment of chemical industries and packaging equipment; basic principles of research of energy efficiency and strength of technological equipment of chemical production enterprises by mathematical modeling methods; examples of the use of numerical analysis for the development of energy-efficient structures and operating regulations for specific industrial equipment with increased mechanical characteristics.

The purpose of the educational component "Scientific work on the topic of the master's thesis. Part 2"

The purpose of the educational component is to form a set of knowledge among students regarding the methods and tools of numerical analysis of energy efficiency, strength and durability of the technological equipment of packaging equipment.

Subject of the educational component "Scientific work on the topic of the master's thesis. Part 2"

– methods and tools of numerical analysis of energy efficiency, strength and durability of technological equipment of packaging equipment.

The study of the educational component enables students to conduct theoretical studies of packaging processes and packaging equipment using modern CAD-CAE design systems.

In accordance with the purpose of training masters in this specialty requires strengthening the formation of the following competencies:

Integral competence:

- The ability to solve complex problems and issues in applied mechanics or during the learning process, which involves conducting research and/or implementing innovations and is characterized by uncertainty in conditions and requirements.

General competences:

- Ability to identify, formulate, and solve engineering, technical, and scientific applied problems (ZK 01);
- The ability to conduct research at an appropriate level (ZK 08).

Professional competencies:

- Ability to apply relevant methods and resources of modern engineering to find optimal solutions to a wide range of engineering tasks using modern approaches, forecasting methods, information technologies, and considering existing constraints under conditions of incomplete information and conflicting requirements (FK 01).
- The ability to apply relevant mathematical, scientific, and technical methods, information technologies, and applied computer software to solve engineering and scientific tasks in the aviation industry (FK 05).

In accordance with the requirements of the program of the educational component, students after its assimilation must demonstrate the following **programmatic learning results**:

- Apply specialized conceptual knowledge of advanced methods and techniques for the design, analysis, and investigation of constructions, machines, and/or processes in the field of mechanical engineering and related knowledge areas (PRN 01);
- Utilize modern methods of parameter optimization of technical systems using systems analysis, mathematical and computer modeling, particularly under conditions of incomplete and conflicting information (PRN 04);
- Independently pose and solve innovative problems, argue and defend obtained results and decisions (PRN 05);
- Clearly and unambiguously present research and project results, convey personal conclusions, arguments, and explanations in both spoken and written form in native and foreign languages to colleagues, learners, and representatives of other professional groups of various levels. (PRN 07);
- Acquire modern knowledge, technologies, tools, and methods, including through independent study of professional literature, participation in scientific and technical and educational events (PRN 08);
- Organize group work in task execution, complex projects, scientific research, understand the work of others, and provide clear instructions (PRN 09);
- Conduct searches for necessary information in scientific and technical literature, electronic databases, and other sources, assimilate, evaluate, and analyze this information (PRN 10);
- Applying fundamental and applied knowledge and skills in the field of innovative engineering technologies in mechanical engineering (PRN 14);

- Conducting experimental and computer-based research utilizing methods of experimental design and mathematical modeling (PRN 15);
- Optimizing technical solutions during the design and operation stages of products and equipment using modern computational algorithms and specialized software suites (PRN 16).

2. Prerequisite and requisition educational components (place in the structural and logical scheme of training according to the relevant educational program)

Prerequisite: educational component "Scientific work on the topic of the master's thesis. Part 2" is based on the study of the following credit modules: "Higher Mathematics", "Physics", "Chemistry", "Engineering and Computer Graphics", "Theoretical Mechanics", "Informatics", "Material science", "Technology of structural materials", "Mechanics of materials and structures", "Theory of mechanisms and machines", "Theoretical foundations of heat engineering", "Machine parts and basics of design", "Mechanics of liquid and gas", "Engineering calculations on computers", "Technologies and equipment for the manufacture of packaging materials", "Packaging technologies and equipment", "Automated engineering systems", "Processes, apparatuses and machines of the industry", "Packaging equipment", "Engineering of packaging equipment".

Postrequisition: credit module "Scientific work on the topic of the master's thesis. Part 2" ensures the implementation of master's dissertations.

3. Contents of the educational component

Chapter 1. Mathematical formulation and method of numerical solution of nonlinear problems of solid medium mechanics

Topic 1.1. Nonlinear unsteady thermal conductivity of an isotropic medium with internal heat sources.

Topic 1.2. The non-linear non-stationary problem of thermal and electrical conductivity.

Topic 1.3. The problem of elastic-plastic behavior of an isotropic material.

Topic 1.4. The problem of elastic-plastic behavior of loose material.

Chapter 2. Development of numerical models and numerical analysis of the thermal, thermoelectric, thermal-hydrodynamic or thermomechanical state of industrial equipment using ANSYS software products

Topic 2.1. Steady-state thermal conductivity of a flat wall under boundary conditions of the I-III genera.

Topic 2.2. Static analysis of structure strength under various force or thermoforce loads.

Topic 2.3. Mixing of fluid streams of different temperatures in a pipe tee.

Topic 2.4. Using a hydrodynamic model with a discrete phase.

Topic 2.5. Cooling of electronic devices due to natural convection and thermal radiation.

Topic 2.6. Tank flushing is a two-phase model (liquid - gas).

Topic 2.7. Dynamic analysis of structure destruction (aluminum can).

4. Educational materials and resources

Basic literature

1. Karvatskii A. Y. Scientific work on the topic of master's thesis. Methods and tools of numerical analysis of physical fields of equipment of chemical production and packaging equipment [Electronic resource]: teaching. posib. for stud. specialties 131 "Applied Mechanics", 133 "Branch Engineering", specialization "Engineering, computer modeling and design of packaging equipment", "Engineering, computer modeling and design of equipment for the production of polymeric and building materials and products". Kyiv: Igor Sikorsky Kyiv Polytechnic Institute, 2018. 234 p. URL : <https://ela.kpi.ua/handle/123456789/23913>
2. Karvatskii A. Y. Engineering of packaging equipment. Lecture notes on the discipline [Electronic resource]: teaching. posib. for stud. specialty 131 "Applied Mechanics", specialization

- "Engineering, computer modeling and design of packaging equipment". Kyiv: Igor Sikorsky Kyiv Polytechnic Institute, 2018. 142 p. URL : <https://ela.kpi.ua/handle/123456789/23915>
3. Karvatskii A. Y. Method of finite elements in problems of mechanics of solid media. Laboratory workshop in the discipline [Electronic resource]: teaching. posib. for stud. specialties 131 "Applied Mechanics", 133 "Branch Engineering", specialization "Engineering, computer modeling and design of packaging equipment", "Engineering, computer modeling and design of equipment for the production of polymeric and building materials and products". Kyiv: Igor Sikorsky Kyiv Polytechnic Institute, 2018. 391 p. Vulture provided by the Methodical Council of Igor Sikorsky Kyiv Polytechnic Institute. URL : <https://ela.kpi.ua/handle/123456789/23916>
 4. Karvatskii A. Y. Nonlinear problems of mechanics of solid media. Computer workshop in the discipline [Electronic resource]: teaching. posib. for stud. specialties 133 "Branch engineering", specialization "Engineering, computer modeling and design of equipment for the production of polymeric and building materials and products". Kyiv: Igor Sikorsky Kyiv Polytechnic Institute. 2019. 158 p. URL : <https://ela.kpi.ua/handle/123456789/27528>
 5. Karvatskii A. Y. Mechanics of solid media. Theoretical foundations of the discipline [Electronic resource]: teaching. posib. for stud. specialties 131 "Applied Mechanics", 133 "Branch Engineering", specialization "Engineering, computer modeling and design of packaging equipment", "Engineering, computer modeling and design of equipment for the production of polymeric and building materials and products". Kyiv: Igor Sikorsky Kyiv Polytechnic Institute, 2018. 290 p. URL : <https://ela.kpi.ua/handle/123456789/23917>

Additional literature

1. Regularities of the process of high-temperature processing of bulk carbon materials in electric furnaces: monograph / T. V. Lazarev, A. Y. Karvatskii, E. M. Panov, S. V. Leleka, A. Y. Pedchenko. Kyiv: NTUU "KPI" "Polytechnic", 2016. 156 p. URL : <https://ela.kpi.ua/handle/123456789/15217>
2. Theoretical and experimental studies of castner graphite furnaces: monograph / A. Y. Pedchenko, E. M. Panov, A. Y. Karvatskii, S. V. Leleka, T. V. Lazarev. Kyiv: Igor Sikorsky Kyiv Polytechnic Institute, 2017. 174 p. URL : <http://ela.kpi.ua/handle/123456789/20800>
3. Energy efficient production of isostatic graphite: monograph / E. M. Panov, S. V. Leleka, A. Y. Karvatskii, I. O. Mikulonok. Kyiv: Igor Sikorsky Kyiv Polytechnic Institute, 2020. 140 c. ISBN 978-617-7734-26-9 URL : <https://ela.kpi.ua/handle/123456789/37590>
4. Energy efficient pressing of coal graphite products: monograph / E. M. Panov, S. V. Leleka, A. Y. Karvatskii, I. O. Mikulonok. Kyiv: Igor Sikorsky Kyiv Polytechnic Institute, 2020. 84 c. ISBN 978-617-7734-27-6 URL : <https://ela.kpi.ua/handle/123456789/37591>
5. Website: OpenFOAM. Open Source Field Operation And Manipulation CFD ToolBox URL: <http://www.openfoam.com/>
6. Website: LIGGGHTS Open Source Discrete Element Method Particle Simulation Code. URL: <https://www.cfdem.com/>
7. Website: ParaView. An open-source, multi-platform data analysis and visualization application. URL: <https://www.paraview.org/>
8. Website: ANSYS Engineering Simulation & 3D Design Software ANSYS [Electronic resource]. URL : <https://www.ansys.com/>
9. Modeling of statics and dynamics of bulk materials in LIGGGHTS [Electronic resource]: teaching. posib. for applicants for master's degree in specialties 131 Applied Mechanics, 133 Branch Engineering / A.Y. Karvatskii, I.O. Mikulonok, V.M. Vytvytsky; KPI them. Igor Sikorsky Kyiv Polytechnic Institute. Electronic text data (1 file: 4.16 MB). – Kyiv: KPI them. Igor Sikorsky Kyiv Polytechnic Institute, 2021. 76 p. URL : <https://ela.kpi.ua/handle/123456789/45613>

Information resources on the Internet

1. DSpace STL Igor Sikorsky Kyiv Polytechnic Institute, <http://ela.kpi.ua/handle/123456789/23913>, <https://ela.kpi.ua/handle/123456789/23915>, <http://ela.kpi.ua/handle/123456789/23916>, <http://ela.kpi.ua/handle/123456789/27528>, <http://ela.kpi.ua/handle/123456789/23917>, <https://ela.kpi.ua/handle/123456789/15217>, <http://ela.kpi.ua/handle/123456789/20800>, <https://ela.kpi.ua/handle/123456789/37590>, <https://ela.kpi.ua/handle/123456789/37591>
2. Website Department of Chemical, Polymeric and Silicate Engineering,, <https://cpsm.kpi.ua/>
3. Campus Igor Sikorsky Kyiv Polytechnic Institute, <http://login.kpi.ua/>
4. Distance learning platform "Sikorsky", <https://sikorsky-distance.kpi.ua/>

Educational content

5. Methods of mastering the educational component

Lecture classes

Lectures are aimed at:

- provision of modern, integral, interdependent knowledge in the educational component "Scientific work on the subject of a master's thesis. Part 2", the level of which is determined by the target attitude to each specific topic;
- ensuring creative work of students together with the teacher during the lecture;
- education of students' professional and business qualities and development of their independent creative thinking;
- formation of students' necessary interest and direction for independent work;
- definition at the current level of the development of science in the field of modern methods of mechanics of continuous environments;
- reflection of the methodical processing of the material (highlighting of the main provisions, conclusions, recommendations, clear and adequate to their wording);
- the use of visual materials for demonstration, their combination, if possible, with the demonstration of calculation results;
- teaching materials of the educational component in clear and high-quality language with observance of structural and logical connections, clarification of all newly introduced terms and concepts;
- accessibility for perception by this audience.

No s/p	The name of the lecture topic and the list of main issues (links to literature and tasks on the SWS)	Number of hours
Chapter 1. Mathematical formulation and method of numerical solution of nonlinear problems of solid medium mechanics		
1	Topic 1.1. Nonlinear unsteady thermal conductivity of an isotropic medium with internal heat sources <u>Lecture 1.</u> Mathematical formulation of the non-linear problem of non-stationary thermal conductivity of an isotropic medium. The method of numerical solution of the problem is based on the finite element method (FEM). <u>Literature:</u> [4] p. 9–12. <u>List of teaching aids:</u> A laptop with an electronic version of the lecture and a projector are used at the lecture. Drawings, posters for the lecture. <u>Tasks on IWS.</u> Software implementation of numerical methods and verification. Mathcad software code for solving the nonlinear problem of non-stationary thermal conductivity of an isotropic medium. <u>Literature:</u> [4] p. 13–18; with. 55–76.	1
2	Topic 1.2. The non-linear non-stationary problem of thermal and electrical conductivity <u>Lecture 2.</u> Mathematical formulation of the non-linear problem of non-	2

No s/p	The name of the lecture topic and the list of main issues (links to literature and tasks on the SWS)	Number of hours
	stationary thermal and electrical conductivity. The method of numerical solution of the problem, built on FEM. <u>Literature</u>: [4] p. 20–25. <u>List of teaching aids</u>: A laptop with an electronic version of the lecture and a projector are used at the lecture. Drawings, posters for the lecture. <u>Tasks on IWS</u>. Software implementation of numerical methods and verification. Mathcad software code for solving the non-linear problem of non-stationary thermal-electrical conductivity of an isotropic medium. <u>Literature</u>: [4] p. 26–30; with. 77–104.	
3	Topic 1.3. The problem of elastic-plastic behavior of an isotropic material <u>Lecture 3</u>. Mathematical formulation of the problem of elastic-plastic behavior of an isotropic material. The method of numerical solution of the problem, built on the implicit algorithm of inverse mapping on the basis of FEM. <u>Literature</u>: [4] p. 32–36. <u>List of teaching aids</u>: A laptop with an electronic version of the lecture and a projector are used at the lecture. Drawings, posters for the lecture. <u>Tasks on IWS</u>. Software implementation of numerical methods and verification. Mathcad software code for solving the problem of elastic-plastic behavior of an isotropic material. <u>Literature</u>: [4] p. 37–42; with. 105–139.	1
4	Topic 1.4. The problem of elastic-plastic behavior of loose material <u>Lecture 4</u>. Mathematical statement of the problem of elastic-plastic behavior of loose material. The method of numerical solution of the problem on the basis of FEM. <u>Literature</u>: [4] p. 44–49. <u>List of teaching aids</u>: A laptop with an electronic version of the lecture and a projector are used at the lecture. Drawings, posters for the lecture. <u>Tasks on IWS</u>. Software implementation of numerical methods and verification. Mathcad software code for solving the problem of elastic-plastic behavior of isotropic flowable material. <u>Literature</u>: [4] p. 49–53; with. 140–147.	2
Chapter 2. Development of numerical models and numerical analysis of the thermal, thermoelectric, thermal-hydrodynamic or thermomechanical state of industrial equipment using ANSYS software products		
5	Topic 2.1. Steady-state thermal conductivity of a flat wall under boundary conditions of the I-III genera <u>Lecture 5</u>. Mathematical formulation of the stationary heat conduction problem. The method of numerical solution of the problem based on the finite volume method (FVM). <u>Literature</u>: lecture notes. <u>List of teaching aids</u>: A laptop with an electronic version of the lecture and a projector are used at the lecture. Drawings, posters for the lecture. <u>Tasks on IWS</u>. Basics of FVM. <u>Literature</u>: lecture notes.	1
6	<u>Lecture 6</u>. Methodology for building a numerical model for solving the problem of stationary thermal conductivity using Workbench Fluent software products. <u>Literature</u>: lecture notes. <u>List of teaching aids</u>: A laptop with an electronic version of the lecture and a projector are used at the lecture. Drawings, posters for the lecture. <u>Tasks on IWS</u>. Construction of a numerical model. <u>Literature</u>: lecture notes; file - "1ua-ANSYS Academic Teaching example 1.pdf".	2
7	Topic 2.2. Static analysis of structure strength under various force or thermoforce loads <u>Lecture 7</u>. Mathematical formulation of the stress-strain state problem. The method of numerical solution of the problem on the basis of MSE. <u>Literature</u>: lecture notes.	1

No s/p	The name of the lecture topic and the list of main issues (links to literature and tasks on the SWS)	Number of hours
	<u>List of teaching aids:</u> A laptop with an electronic version of the lecture and a projector are used at the lecture. Drawings, posters for the lecture. <u>Tasks on IWS.</u> Static analysis of structural strength (plate). Boundary conditions. <u>Literature:</u> lecture notes.	
8	<u>Lecture 8.</u> Methodology for building a numerical model for solving the problem of static analysis of plate strength using Workbench software products. <u>Literature:</u> lecture notes. <u>List of teaching aids:</u> A laptop with an electronic version of the lecture and a projector are used at the lecture. Drawings, posters for the lecture. <u>Tasks on IWS.</u> Construction of a numerical model. <u>Literature:</u> lecture notes; file - "ANSYS Mechanical static analysis of structural strength (plate) .pdf".	2
9	Topic 2.3. Mixing of fluid streams of different temperatures in a pipe tee <u>Lecture 9.</u> Mathematical formulation of the problem of thermal and hydrodynamics during the turbulent flow of an incompressible Newtonian fluid based on the standard model. Construction of the geometry of the pipe tee and implementation of discretization with the construction of the boundary layer. <u>Literature:</u> lecture notes. <u>List of teaching aids:</u> A laptop with an electronic version of the lecture and a projector are used at the lecture. Drawings, posters for the lecture. <u>Tasks on IWS.</u> Mixing of fluid streams of different temperatures in a pipe tee. Boundary conditions. <u>Literature:</u> lecture notes.	1
10	<u>Lecture 10.</u> Methodology for building a numerical model for solving the problem of mixing fluid flows of different temperatures in a pipe tee using Workbench Fluent software products. <u>Literature:</u> lecture notes. <u>List of teaching aids:</u> A laptop with an electronic version of the lecture and a projector are used at the lecture. Drawings, posters for the lecture. <u>Tasks on IWS.</u> Construction of a numerical model. Construction of the geometry of the pipe tee and implementation of discretization with the construction of the boundary layer. <u>Literature:</u> lecture notes; file - fluent_13.0_workshop01-mixingtee.pdf.	2
11	Topic 2.4. Using a hydrodynamic model with a discrete phase <u>Lecture 11.</u> Mathematical formulation of the continuous-discrete problem of non-isothermal two-phase flow (gas - liquid drops or liquid - solid particles). <u>Literature:</u> lecture notes. <u>List of teaching aids:</u> A laptop with an electronic version of the lecture and a projector are used at the lecture. Drawings, posters for the lecture. <u>Tasks on IWS.</u> Using a discrete-phase model to simulate isothermal two-phase flow in a reactor. Boundary conditions. <u>Literature:</u> lecture notes.	1
12	<u>Lecture 12.</u> Methodology for building a numerical model for solving the problem of isothermal two-phase flow in a reactor using Workbench Fluent software products. <u>Literature:</u> lecture notes. <u>List of teaching aids:</u> A laptop with an electronic version of the lecture and a projector are used at the lecture. Drawings, posters for the lecture. <u>Tasks on IWS.</u> Construction of a numerical model for solving the problem of isothermal two-phase flow in a reactor using Workbench Fluent software products. <u>Literature:</u> lecture notes; the file is fluent_13.0_workshop06-dpm.pdf.	2
13	Topic 2.5. Cooling of electronic devices due to natural convection and thermal radiation	2

No s/p	The name of the lecture topic and the list of main issues (links to literature and tasks on the SWS)	Number of hours
	<u>Lecture 13.</u> Mathematical formulation of the problem of thermal-hydrodynamics during the laminar flow of an incompressible ideal fluid taking into account radiation heat transfer. <u>Literature:</u> lecture notes. <u>List of teaching aids:</u> A laptop with an electronic version of the lecture and a projector are used at the lecture. Drawings, posters for the lecture. <u>Tasks on IWS.</u> Cooling of electronic devices due to natural convection and thermal radiation. Boundary conditions. <u>Literature:</u> lecture notes.	
14	<u>Lecture 14.</u> Methodology for building a numerical model for solving the problem of cooling electronic devices due to natural convection and thermal radiation using Workbench Fluent software products. <u>Literature:</u> lecture notes. <u>List of teaching aids:</u> A laptop with an electronic version of the lecture and a projector are used at the lecture. Drawings, posters for the lecture. <u>Tasks on IWS.</u> Construction of a numerical model for solving the problem of cooling electronic devices due to natural convection and thermal radiation. <u>Literature:</u> lecture notes; file - fluent_13.0_workshop04-electronics.pdf.	2
15	Topic 2.6. Tank flushing - two-phase model (liquid - gas) <u>Lecture 15.</u> Mathematical formulation of the two-phase flow problem flow based on the VOF model. <u>Literature:</u> lecture notes. <u>List of teaching aids:</u> A laptop with an electronic version of the lecture and a projector are used at the lecture. Drawings, posters for the lecture. <u>Tasks on IWS.</u> Tank flushing is a two-phase model. Boundary conditions. <u>Literature:</u> lecture notes.	2
16	<u>Lecture 16.</u> Methodology for building a numerical model for solving the problem of tank flushing - a two-phase VOF model using Workbench Fluent software products. <u>Literature:</u> lecture notes. <u>List of teaching aids:</u> A laptop with an electronic version of the lecture and a projector are used at the lecture. Drawings, posters for the lecture. <u>Tasks on IWS.</u> Construction of a numerical model for solving the problem of tank flushing - a two-phase VOF model. <u>Literature:</u> lecture notes; file - fluent_13.0_workshop07-tank-flush.pdf.	2
17	Topic 2.7. Dynamic analysis of structure destruction (aluminum can) <u>Lecture 17.</u> Mathematical statement of the problem of dynamic analysis of structure destruction. <u>Literature:</u> lecture notes. <u>List of teaching aids:</u> A laptop with an electronic version of the lecture and a projector are used at the lecture. Drawings, posters for the lecture. <u>Tasks on IWS.</u> Dynamic analysis of the destruction of the aluminum can structure. Boundary conditions. <u>Literature:</u> lecture notes.	2
18	<u>Lecture 18.</u> Methodology for building a numerical model for solving the problem of dynamic analysis of the collapse of an aluminum can structure using Workbench Fluent software products. <u>Literature:</u> lecture notes. <u>List of teaching aids:</u> A laptop with an electronic version of the lecture and a projector are used at the lecture. Drawings, posters for the lecture. <u>Tasks on IWS.</u> Construction of a numerical model for solving the problem of dynamic analysis of the destruction of the aluminum can structure. <u>Literature:</u> lecture notes; file –task8 Explicit Dynamics LS-DYNA.pdf.	2
Total		30

Practical classes

The main tasks of the cycle of practical classes are the application by students of theoretical foundations for the construction of physical and mathematical models of thermal, thermal electrodynamic, heat-hydrodynamic and thermomechanical state of industrial equipment of packaging machinery [1–5] for the development of numerical models of physical condition, in particular thermal, thermal and thermal and thermal mechanic state of industrial equipment of packaging equipment [A1–A4] using workbench software products [6], Workbench Fluent [6], OpenFOAM and LIGGGHTS [A5–A7], conducting a numerical analysis of the thermal, heat-hydrodynamic or thermomechanical state of packaging equipment.

No s/p	The name of the topic of practical classes and the list of main issues (reference to literature and tasks on the SWS)	Number of hours
1	Computer workshop 1. Stationary thermal conductivity of a flat wall, Workbench Fluent – a file of methodical developments – "1ua-ANSYS Academic Teaching example 1.pdf" [6]. <u>Tasks on the IWS.</u> Mathematical formulation of stationary and nonstationary problems of thermal conductivity. Methods of numerical solution of problems. <u>Literature:</u> [1] p. 10–16, p. 81–126; [2] 105–106, 109–111; [3] p. 8–9, 23–84, 170–191; [4] p. 9–19. Nonlinear nonstationary problem of thermal conductivity. Mathematical formulation of a nonlinear problem and the methodology of its numerical solution. <u>Literature:</u> [1] 178–180; [2] 112–114; [4] 20–30.	1
2	Computer workshop 2. Static analysis of structural strength (plate) Workbench – file of methodical developments – "ANSYS Mechanical static analysis of structural strength (plate) .pdf" [6]. <u>Tasks on the IWS.</u> Mathematical formulation of the linear problem of static elasticity. Method of numerical solution of the problem. <u>Literature:</u> [1] 181–184; [2] 106–109; [3] p. 9–18, 87–127, 193–216. Mathematical formulation of the problem of dynamic elasticity, taking into account large deformations and contact interaction of mechanical nature. <u>Literature:</u> [2] 111–112. Mathematical formulation of the bound problem of thermal elasticity. <u>Literature:</u> [2] 114–116. The problem of elastic-plastic behavior of isotropic material. Mathematical formulation of a nonlinear problem and the methodology of its numerical solution. <u>Literature:</u> [4] 32–42.	1
3	Computer workshop 3. Mixing fluid fluid flows of different temperatures in the pipe tee – Fluid Flow and Heat Transfer in a Mixing Tee, Workbench Fluent – methodical development file – "fluent_13.0_workshop01-mixingtee.pdf", model sampling file – "fluidtee.meshdat" [6]. Calculations of material and thermal balances. <u>Tasks on the IWS.</u> Mathematical formulation of the problem of heat-hydrodynamics during the laminar flow of incompressible Newtonian fluid. <u>Literature:</u> [2] 117–120. Mathematical formulation of the heat-hydrodynamics problem during the turbulent flow of incompressible Newtonian fluid on the basis of standard $k - \varepsilon$ model. <u>Literature:</u> [2] 120–122. Finite volume method. <u>Literature:</u> [1] 127–139. Methods of compiling energy and thermal balances of industrial equipment. <u>Literature:</u> [1] 185–190.	1
4	Computer workshop 4. Construction of pipe tee geometry and sampling for KP3. Workbench – DesignModeler, Meshing [6].	1

No s/p	The name of the topic of practical classes and the list of main issues (reference to literature and tasks on the SWS)	Number of hours
	<i>Tasks on the IWS. Physical equations for newton fluid. Literature: [2] 123–124. Examples of the use of mathematical modeling for the development of energy-saving structures and regulations for the operation of industrial equipment. Literature: [1] 198–227.</i>	
5	Computer workshop 5. Using the Discrete Phase Model (DPM), Workbench Fluent – methodical development file – "fluent_13.0_workshop06-dpm.pdf", model sampling file – "dpm_tutorial.msh" [6]. <i>Tasks on the IWS. Mathematical models of dilatant (composite) substances. Setting a heat-hydrodynamic problem for a liquid of type Bingham-Papanastasiou. Literature: [2] 124–127.</i> <i>Mathematical model of the process of impregnation of torn media during the manufacture of composite containers. Literature: [2] 127–129.</i>	1
6	Computer workshop 6. Cooling of electronic devices due to natural convection and thermal radiation – Electronics Cooling with Natural Convection and Radiation, Workbench Fluent – folder of methodical developments – "workshop4-electronics", model sampling file – "heatsink.msh.gz" [6]. Calculations of material and thermal balances. <i>Tasks on the IWS. Methods of compiling energy and thermal balances of industrial equipment. Literature: [1] 191–197.</i>	1
7	Computer workshop 7. Flushing the tank is a two-phase model. Tank Flushing Example, Workbench Fluent – file method. developments – "fluent_13.0_workshop07-tank-flush.pdf", mesh – file "tankflush.msh.gz" [6]. <i>Tasks on the IWS. Mathematical formulation of the problem of flow of two-phase flow on the basis of the VOF model. Mathematical formulation of the problem of the flow of multiphase flow on the basis of euler's model. Literature: [6].</i>	2
8	Computer workshop 8. Dynamic analysis of structure destruction (aluminum can). task 8 Explicit Dynamics LS-DYNA, Workbench – method file. Development; soda_can.agdb – geometric model file [6]. <i>Tasks on IWS. Mathematical formulation of the problem of dynamic analysis of structure destruction. Literature: synopsis of lectures.</i> <i>The method of building a numerical model of the problem of dynamic analysis of the destruction of the structure of an aluminum can. Literature: synopsis of lectures.</i>	2
9	Modular control work	2
10	Test	2
Total		14

Seminars

According to the working curriculum, seminars are not provided.

Laboratory classes

According to the working curriculum, laboratory classes are not provided.

6. Independent work of the student

No s/p	Name of the topic submitted for self-study	Number of hours of IWS
Chapter 1. Mathematical formulation and method of numerical solution of nonlinear problems of solid medium mechanics		
1	Topic 1.3. The problem of elastic-plastic behavior of an isotropic material	8

No s/p	Name of the topic submitted for self-study	Number of hours of IWS
	<i>Mathematical formulation of the problem of elastic-plastic behavior of an isotropic material. The method of numerical solution of the problem, built on the implicit algorithm of inverse mapping. Literature: [4] p. 32–36.</i> <i>Software implementation of numerical methods and verification. Mathcad software code for solving the problem of elastic-plastic behavior of an isotropic material. Literature: [4] p. 37–42; with. 105–139.</i>	
2	Topic 1.4. The problem of elastic-plastic behavior of loose material <i>Mathematical statement of the problem of elastic-plastic behavior of loose material. The method of numerical solution of the problem. Literature: [4] p. 44–49.</i> <i>Software implementation of numerical methods and verification. Mathcad software code for solving the problem of elastic-plastic behavior of isotropic flowable material. Literature: [4] p. 49–53; with. 140–147.</i>	8
Chapter 2. Development of numerical models and numerical analysis of the thermal, thermoelectric, thermal-hydrodynamic or thermomechanical state of industrial equipment using ANSYS software products		
3	Topic 2.1. Steady-state thermal conductivity of a flat wall under boundary conditions of the I-III genera <i>Mathematical formulation of stationary and non-stationary heat conduction problems. Methods of numerical problem solving. Literature: [1] p. 10–16, p. 81–126; [2] p. 105–106, p. 109–111; [3] p. 8–9, p. 23–84, p. 170–191; [4] p. 9–19.</i> <i>The non-linear non-stationary problem of thermal and electrical conductivity. Mathematical formulation of a nonlinear problem and the method of its numerical solution. Literature: [1] p. 178–180; [2] p. 112–114; [4] p. 20–30.</i>	8
4	Topic 2.2. Static analysis of structure strength under various force or thermoforce loads <i>Mathematical formulation of the linear problem of static elasticity. The method of numerical solution of the problem. Literature: [1] p. 181–184; [2] p. 106–109; [3] p. 9–18, p. 87–127, p. 193–216.</i> <i>Mathematical formulation of the problem of dynamic elasticity taking into account large deformations and contact interaction of a mechanical nature. Literature: [2] p. 111–112.</i> <i>Mathematical formulation of the coupled problem of thermo-elasticity. Literature: [2] p. 114–116.</i> <i>The problem of elastic-plastic behavior of an isotropic material. Mathematical formulation of a nonlinear problem and the method of its numerical solution. Literature: [4] p. 32–42.</i>	8
5	Topic 2.3. Mixing of fluid streams of different temperatures in a pipe tee <i>Mathematical formulation of the problem of thermo-hydrodynamics during laminar flow of an incompressible Newtonian fluid. Literature: [2] p. 117–120.</i> <i>Construction of the geometry of the pipe tee and implementation of discretization with the construction of the boundary layer. Physical equations for a non-Newtonian fluid. Literature: [2] p. 123–124.</i> <i>Mathematical formulation of the problem of thermo-hydrodynamics during the turbulent flow of an incompressible Newtonian fluid based on the standard model. Literature: [2] p. 120–122.</i> <i>The method of finite volumes. Literature: [1] p. 127–139.</i>	8

No s/p	Name of the topic submitted for self-study	Number of hours of IWS
	<i>Methods of drawing up energy and heat balances of industrial equipment. Literature: [1] p. 185–190. Examples of the application of mathematical modeling for the development of energy-saving structures and regulations for the operation of industrial equipment. Literature: [1] p. 198–227.</i>	
6	Topic 2.4. Using a hydrodynamic model with a discrete phase <i>Mathematical models of dilatant (composite) substances. Formulation of the thermo-hydrodynamic problem for a liquid of the Bingham-Papanastasiou type. Literature: [2] p. 124–127.</i> <i>Mathematical model of the impregnation process of porous media during the manufacture of composite containers. Literature: [2] p. 127–129.</i>	6
7	Topic 2.5. Cooling of electronic devices due to natural convection and thermal radiation <i>Methods of drawing up energy and heat balances of industrial equipment. Literature: [1] p. 191–197.</i>	6
8	Topic 2.6. Tank flushing - two-phase model (liquid - gas) <i>Mathematical formulation of the two-phase flow problem based on the VOF model. Mathematical formulation of the multiphase flow problem based on the Euler model. Literature: [6].</i>	6
9	Topic 2.7. Dynamic analysis of structure destruction (aluminum can) <i>Mathematical formulation of the problem of dynamic analysis of structure destruction. Literature: lecture notes.</i> <i>The method of building a numerical model of the problem of dynamic analysis of the destruction of the structure of an aluminum can. Literature: [6]; lecture notes.</i>	8
10	Modular control work	4
11	Test	6
Total		76

Individual tasks

According to the working curriculum, individual tasks are not provided.

Control works

The purpose of the modular control work:

- a summary of the study of sections and topics of the credit module;
- application of acquired knowledge to perform engineering calculations;
- the ability to independently apply the acquired knowledge to perform tasks in this credit module and in other educational components: "Packaging equipment", "Research and engineering of packaging equipment. Course project", "Scientific work on the topic of a master's thesis".

The curriculum of the educational component provides for one modular control paper, which covers sections 1 and 2. An approximate list of questions for the MCW is given at the end of the Syllabus. The wording of the questions for the MCW can be slightly changed in accordance with the peculiarities of teaching the lecture material and its perception by students. In order to prepare students in the IWS mode, the teacher familiarizes them with the questions for the MKR 1-2 weeks before the assignment. A package of tasks for the MCW has been developed.

7. Policy of educational component

Rules for attending classes and behavior in classes

Attending classes is a mandatory component of assessment. Students are obliged to take an active part in the educational process, not to be late for classes and not to miss them without a good reason, not to interfere with the teacher to conduct classes, not to be distracted by actions that are not related to the educational process.

Rules for the implementation and protection of practical work (computer workshops):

- practical work (computer workshops) takes place during hours of practical classes and SRS and is sent to the teacher's e-mail or telegrams;
- in accordance with the "Code of Honor" practical work (computer workshops) and preparation of answers to theoretical and practical questions students perform independently;
- rules for the protection of practical works (computer workshops) are based on a rating system for assessing learning outcomes.

Rules for assigning incentive and penalty points:

- encouraging points can be credited by the teacher for the preparation of scientific publications on the topics of the educational component. At the same time, the amount of incentive points may not exceed 25% of the rating scale;
- penalty points within the educational component are not provided.

Deadline and overlay policy

In case of debts in the educational component or any force majeure circumstances, students should contact the teacher through accessible (provided by the teacher) communication channels to solve problematic issues and coordinate the algorithm of actions for working out.

Academic Integrity Policy

Violation of the Code of Academic Integrity of the National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute" is a serious violation, even if it is unintentional. The Code is available at the link: <https://kpi.ua/code.3>. In particular, compliance with the Code of Academic Integrity means that all work in exams and tests must be performed individually. When doing independent work, students can consult with teachers and other students, but must independently solve problems, guided by their own knowledge, skills and abilities. References to all resources and sources (e.g. in reports from computer workshops, independent work or presentations) should be clearly defined and properly executed. That is, it is unacceptable to have no references when using printed and electronic materials, quotes, opinions of other authors.

Policy of academic behavior and ethics

Students should be tolerant, respect the opinion of others, object to formulate in the correct form, constructively maintain feedback in the classroom. The norms of ethical behavior of students and employees are defined in Section 2 of the Code of Honor of the National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute". More: <https://kpi.ua/code.2>.

8. Types of control and rating system for assessing learning outcomes (RS)

Distribution of educational time by types of classes and tasks from the credit module according to the working curriculum:

Semester	School time		Distribution of training hours				Control measures		
	credit	acad. h.	Lecture	Pract.	Labor.	IWS	MCW	CGW	Semester certification
2	4	120	30	14	–	76	1	–	test

Current control: answers to questions of express control of theoretical material, reports from computer workshops, modular control work.

Calendar control: conducted twice a semester as monitoring of the current state of compliance with the requirements of the syllabus.

Semester control: test.

The student's rating in the educational component consists of points that he receives for:

- 1) answers to the questions of express control of theoretical material (4 express control is carried out);
- 2) performance of computer workshops in practical classes (8 works in total);
- 3) modular control work.

System of rating (weight) points and evaluation criteria

1. Express control:

- "excellent", full answer (at least 90% of the necessary information) – 4 points;
- "good", a sufficiently complete answer (at least 75% of the required information), or a complete answer with minor inaccuracies – 3 points;
- "satisfactory", incomplete response (at least 60% of the necessary information) and minor errors – 1 points;
- "unsatisfactory", unsatisfactory answer (does not meet the requirements for 1 point) – 0 points.

2. Practical classes:

- "excellent", creative execution of the task, fluency in the material – 7-8 points;
- "good", complete the task in full – 5-6 points;
- "satisfactory", completing the task with some minor errors – 3-4 points;
- "unsatisfactory", non-fulfillment of the task – 0 points.

3. Modular control work:

- "excellent", complete answer (at least 90% of the required information) - 19-20 points;
- "good", a sufficiently complete answer (at least 75% of the required information), or a complete answer with minor inaccuracies - 14-15 points;
- "satisfactory", incomplete answer (at least 60% of the required information) and minor errors - 11-12 points;
- "unsatisfactory", an unsatisfactory answer - 0 points.

One or two best students at each practical lesson may be added 1-2 encouraging points; +5 encouraging points for a report on the results of studying the educational component at a student conference or publication in a journal.

According to the results of educational work for the first 7 weeks, the "ideal student" should score 50 points. At the certification (8th week), the student receives "enrolled" if his current rating is not less than 25 points.

According to the results of 15 weeks, the "ideal student" should score 100 points. At the second certification (week 16), the student receives "enrolled" if his current rating is not less than 50 points.

The maximum amount of points for semester R is 100 (where $R = r_{pr} \cdot 8 + r_{e-kp} \cdot 4 + r_{MKR} = 8 \cdot 8 + 4 \cdot 4 + 16 = 64 + 16 + 20 = 100$). To obtain a credit module score from the "automatic" module, you need to have a rating of at least 60 points.

Students who have a rating of less than 60 points at the end of the semester, as well as those who want to increase their grade, perform scoring control work. The task of scoring control work consists of two issues (one theoretical and one practical) of different topics of the working program from the list provided in the methodological recommendations for the assimilation of the credit module. Additional

questions on the topics of practical classes are received by students who did not participate in the work of a particular lesson.

The theoretical question of scoring control work (r_1) is estimated at 40 points, and the practical (r_2) at 60 points, according to the evaluation system.

The system of evaluation of the theoretical question:

- "excellent", full answer (at least 90% of the necessary information) – 40-37 points;
- "good", a sufficiently complete answer (at least 75% of the necessary information or minor inaccuracies) – 30-28 points;
- "satisfactory", incomplete answer (at least 60% of the necessary information and some errors) – 34-22 points;
- "unsatisfactory", unsatisfactory answer – 0 points.

The system of evaluation of the practical task:

- "excellent", complete unmistakable solution of the problem (at least 90% of the necessary information) – 60-55 points;
- "good", complete solution of the problem with insignificant inaccuracies (at least 75% of the necessary information or minor inaccuracies) – 45-40 points;
- "satisfactory", the task is performed with certain shortcomings (at least 60% of the necessary information and some errors) – 36-30 points;
- "unsatisfactory", the task is not completed – 0 points.

The rating of the credit module is:

$$R = r_1 + r_2,$$

where r_1 , r_2 – rating for scoring control work, respectively, for each of the two issues of scoring control work.

That is, $R = 40 + 60 = 100$ points.

Terms of admission to semester control: semester rating of more than 40 points.

The amount of points for each of the three questions of the control work is transferred to the scoring assessment according to the table:

Table of conformity of rating points on the university scale:

Number of points	Estimation
100-95	Perfectly
94-85	Very good
84-75	Good
74-65	Satisfactory
64-60	Enough
Less 60	Unsatisfactorily
Admission conditions not met	Not allowed

9. Additional information on the educational component

List of questions submitted for semester control

1. Analyze the formulation of the problem of stationary thermal conductivity and describe the boundary conditions.
2. Describe the formulation of the problem of static elasticity and describe the boundary conditions of this task.

3. *Analyze the boundary conditions of the contact type of the static elasticity problem.*
4. *Analyze the Duhamel-Neumann equation and describe its components.*
5. *Analyze and compare the formulas for calculating the safety margin of the structure for plastic and fragile materials.*
6. *Describe the formulation of the problem of nonstationary thermal conductivity and give the appropriate initial and boundary conditions.*
7. *Analyze the formulation of the problem of dynamic elasticity, taking into account large deformations and contact interaction of mechanical nature.*
8. *Analyze the formulation of the problem of a nonlinear nonstationary thermoelectric problem and formulate the appropriate conditions of unambiguousness.*
9. *Describe the formulation of the related problem of thermal elasticity and give the appropriate initial and boundary conditions.*
10. *Analyze the formulation of the heat-hydrodynamics problem during the laminar flow of the incompressible Newtonian fluid and describe the appropriate initial and boundary conditions.*
11. *Analyze the formulation of the heat-hydrodynamics problem during the turbulent flow of the incompressible Newtonian liquid on the basis of a standard model with appropriate initial and boundary conditions.*
12. *Describe the physical equations for neneutonic fluid.*
13. *Reproduce the setting of the heat-hydrodynamic problem for a liquid of type Bingham-Papanastasiou.*
14. *Describe the mathematical model of the process of impregnation of torn media.*
15. *Analyze the formulation of the problem of a moving layer of bulk material with the appropriate conditions of unambiguousness.*
16. *Analyze the order of construction and execution of calculations according to the numerical model of the problem of stationary thermal conductivity of a flat wall using Workbench Fluent software products.*
17. *Describe the algorithm for constructing a numerical model of the static elasticity problem and performing a static analysis of plate strength in workbench software.*
18. *Analyze the order of construction of the numerical model of the heat-hydrodynamic state problem on the example of the problem of mixing fluid flows of different temperatures in the pipe tee using Workbench Fluent software products.*
19. *Analyze the order of construction of the geometry of the pipe tee and perform sampling with the construction of a border layer using Workbench – DesignModeler, Meshing software products.*
20. *Analyze the algorithm for constructing and performing calculations on a numerical model of a problem with a discrete phase using Workbench Fluent software products.*
21. *Analyze the algorithm for constructing and performing calculations according to the numerical model of the problem of cooling electronic devices due to natural convection and thermal radiation using Workbench Fluent software products.*
22. *Reproduce the order of construction and execution of calculations according to the numerical model of the tank flushing problem – a two-phase model (liquid - gas) using Workbench Fluent software products.*
23. *Analyze the algorithm for constructing and performing calculations according to the numerical model of the problem of determining the angle of natural slope based on the results of modeling the process of forming a slide of bulk material.*

List of questions and tasks that are assigned to the modular control work

1. *Analyze the statement of the problem of stationary thermal conductivity and describe the boundary conditions.*
2. *Describe the formulation of the problem of static elasticity and describe the boundary conditions of this problem.*
3. *Analyze the boundary conditions of the contact type of the problem of static elasticity.*
4. *Analyze the Duhamel-Neumann equation and characterize its components.*

5. *Analyze and compare the formulas for calculating the structural safety margin for ductile and brittle materials.*
6. *Describe the formulation of the non-stationary thermal conductivity problem and state the corresponding initial and boundary conditions.*
7. *Analyze the formulation of the problem of dynamic elasticity, taking into account large deformations and contact interaction of a mechanical nature.*
8. *Analyze the formulation of the problem of the non-linear non-stationary thermoelectric problem and formulate the appropriate conditions of uniqueness.*
9. *Describe the formulation of the coupled problem of thermoelasticity and state the corresponding initial and boundary conditions.*
10. *Analyze the formulation of the problem of thermo-hydrodynamics during the laminar flow of an incompressible Newtonian fluid and describe the corresponding initial and boundary conditions.*
11. *Analyze the formulation of the problem of thermo-hydrodynamics during the turbulent flow of an incompressible Newtonian fluid on the basis of a standard model with appropriate initial and boundary conditions.*
12. *Describe the physical equations for a non-Newtonian fluid.*
13. *Reproduce the formulation of the thermo-hydrodynamic problem for a liquid of the Bingham-Papanastasiou type.*
14. *Describe the mathematical model of the impregnation process of porous media.*
15. *Analyze the formulation of the problem of the moving layer of bulk material with the corresponding conditions of uniqueness.*
16. *Analyze the procedure for building and performing calculations according to the numerical model of the problem of stationary thermal conductivity of a flat wall using Workbench Fluent software products.*
17. *Describe the algorithm for building a numerical model of the problem of static elasticity and performing a static analysis of plate strength in the Workbench software.*
18. *Analyze the procedure for building a numerical model of the thermal-hydrodynamic state problem using the example of the problem of mixing fluid flows of different temperatures in a pipe tee using Workbench Fluent software products.*
19. *Analyze the procedure for building the geometry of a pipe tee and performing discretization with the construction of a boundary layer using Workbench software products – Design Modeler, Meshing.*
20. *Analyze the algorithm for building and performing calculations based on a numerical model of a problem with a discrete phase using Workbench Fluent software products.*
21. *Analyze the algorithm for building and performing calculations based on a numerical model of the problem of cooling electronic devices due to natural convection and thermal radiation using Workbench Fluent software products.*
22. *Reproduce the procedure for building and performing calculations based on the numerical model of the tank flushing problem - a two-phase model (liquid - gas) using Workbench Fluent software products.*
23. *Analyze the algorithm for building and performing calculations based on a numerical model of the problem of determining the angle of a natural slope based on the results of modeling the process of forming a hill of loose material.*

Work program of the educational component (syllabus):

Compiled by Professor, Doctor of Technical Sciences, Professor, Anton KARVATSKYI

Approved by the Department of Chemical, Polymeric and Silicate Engineering (Protocol No. 17 of 04.06.2025)

Approved by the Faculty Methodical Commission (Protocol No. 11 of 27.06.2025)