

APPLIED PROBLEMS OF CONTINUUM MECHANICS

Educational component work program (Syllabus)

Educational component details

Level of higher education	Second (Master's)
Branch of knowledge	13 Mechanical engineering
Speciality	131 Applied Mechanics
Educational program	Educational and Scientific Program Engineering of packaging products, processes and equipment
Status of educational component	Selective
Form of training	full-time / day
Year of preparation, semester	2 course, autumn semester
Volume of educational component	5 (150)
Semester control/ control measures	Exam
Schedule of classes	
Language of instruction	Ukrainian
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: https://cpsm.kpi.ua/karvatskij-anton-yanovich.html
Course placement	Link to remote resource Google classroom, https://cpsm.kpi.ua/navchannya/sylabusy/sylabusy-2025-roku.html

Educational component program

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

Educational component "Applied problems of continuum mechanics" are the most important link that logically combines the disparate knowledge gained by students during the study of individual educational components into a single system of knowledge that ensures the high quality of scientific and applied design developments, has a theoretical and practical direction in the training of specialists specializing in the field of applied mechanics.

The subject of the educational component "Applied problems of the mechanics of continuum mechanics" is methods for studying the stress-deformed state of solid, liquid and gaseous bodies in their interaction with each other and physical fields of different physical nature – gravitational, thermal, electromagnetic, radiation, etc.

The purpose of the educational component "Applied problems continuum mechanics"

The purpose of the educational component is to strengthen the process of formation of a set of knowledge by students on the theoretical foundations and practical skills of performing studies of the stress-deformed state of solid, liquid and gaseous bodies in their interaction with each other and physical fields of different physical nature – gravitational, thermal, electromagnetic, radial, etc.

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 tasks and problems in applied mechanics or in the learning process, which involves conducting research and/or implementing innovations and is characterized by uncertainty of conditions and requirements.

General competences:

- Ability to identify, pose and solve engineering, technical and scientific and applied problems (ZK 01);
- Ability to use information and communication technologies (ZK 02);
- Ability to generate new ideas (creativity) (ZK 03);
- Ability to learn and master modern knowledge (ZK 06).

Professional competencies:

- Ability to apply appropriate methods and resources of modern engineering to find optimal solutions to a wide range of engineering problems using modern approaches, forecasting methods, information technologies and taking into account existing limitations under conditions of incomplete information and conflicting requirements (FC 01);
- Ability to describe, classify and model a wide range of technical objects and processes, based on deep knowledge and understanding of theories and practices of mechanical engineering, as well as knowledge of related sciences (FC 02);
- Ability to plan and carry out experimental and theoretical research in applied mechanics and related interdisciplinary problems, to process and generalize research results (FC 05);
- Ability to apply fundamental and applied knowledge and skills in the field of innovative technologies of mechanical engineering (FC 07);
- Ability to apply appropriate mathematical, scientific and technical methods, information technologies and applied computer software to solve engineering and scientific problems in applied mechanics (FC 08);
- Ability to critically analyze and predict the performance parameters of new and existing mechanical structures, machines, materials and production processes of mechanical engineering based on knowledge and use of modern analytical and/or computerized methods and techniques (FC 09).

According to the requirements of the program of the educational component "Applied problems of continuum mechanics", students after its assimilation must demonstrate the following enhanced programmatic learning results:

- Apply specialized conceptual knowledge of the latest methods and techniques for designing, analyzing and researching structures, machines and/or processes in the field of mechanical engineering and related fields of knowledge (PRN 01);
- Apply fundamental and applied knowledge and skills in the field of innovative technologies of mechanical engineering (PRN 14);
- Conduct experimental and computer research using methods of experimental planning and mathematical modeling (PRN 15);
- Optimize technical solutions at the stage of designing and operating products and equipment using modern calculation algorithms and specialized software packages (PRN 16).

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

Prerequisite: the educational component "Applied problems of continuum mechanics" is based on the study of the following credit modules: "Higher Mathematics", "Physics", "Chemistry", "Engineering and Computer Graphics", "Theoretical Mechanics", "Informatics", "Materials 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", "Mechanics of continuum".

Postrequisition: credit module "Applied problems of continuum mechanics" provides the following educational components: "Packaging equipment", "CAD of technological equipment", "Course project on engineering of packaging equipment" and "Scientific work on the topic of master's thesis", master's dissertations.

3. Contents of the educational component

Section 1. Mathematical models are based on the Eulerian reference system

Topic 1.1. Models of turbulence.

Topic 1.2. Models of the flow of reactive media.

Topic 1.3. Examples of the use of turbulence models and the flow of reactive environments.

Section 2. Mathematical models are based on the Lagrangian reference system

Topic 2.1. Models of statics, dynamics and heat exchange of bulk materials.

Topic 2.2. Examples of using static models, dynamics and heat exchange of bulk materials.

Section 3. Mathematical models are based on continuum-discrete approximation

Topic 3.1. Models of nonisothermic two-phase flow (gas – liquid drops or liquid – particulate matter).

Topic 3.2. Models of gasification of solid fuel.

Topic 3.3. Examples of using continuum-discrete models.

4. Educational materials and resources

Basic literature

1. Applied problems of the mechanics of solid media. [Electronic resource]: synopsis of lectures: teaching. manual for master's degree holders in education. program "Engineering of packaging and packaging equipment" special. 131 "Applied Mechanics" / A. Ya. Karvatskyi; KPI named after Igor Sikorsky. - Electron. text. data (1 file: 7.3 MB). – Kyiv: KPI named after Igor Sikorskyi, 2023. 171 p. URL : <https://ela.kpi.ua/handle/123456789/23917>

2. 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; Igor Sikorsky Kyiv Polytechnic Institute. Electronic text data (1 file: 4.16 MB). Kyiv: Igor Sikorsky Kyiv Polytechnic Institute, 2021. 76 p. URL : <https://ela.kpi.ua/handle/123456789/45613>

3. Karvatskii A. Y. Mechanics of solid media – 2. Nonlinear problems of the mechanics of solid media. Workshop on the educational component [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, 2018. 390 p. URL : <https://ela.kpi.ua/handle/123456789/23918>

4. Karvatskii A. Y. Method of finite elements in problems of mechanics of solid media. Laboratory workshop in the educational component [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. URL : <http://ela.kpi.ua/handle/123456789/23916>

5. 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>

Additional literature

1. Poinot T., Veynante D. Theoretical and numerical combustion. 2nd ed. Philadelphia : Edwards, 2005. 522 p.

2. Website: ANSYS Engineering Simulation & 3D Design Software ANSYS [Електронний ресурс]. URL : <https://www.ansys.com/>

3. Website: LIGGGHTS Open Source Discrete Element Method Particle Simulation Code. URL : <https://www.cfdem.com/>

4. Website: ParaView. An open-source, multi-platform data analysis and visualization application. URL: <https://www.paraview.org/>

5. Theoretical and experimental studies of thermal and mechanical state of high-temperature units: monogr. / A. Y. Karvatsky, E. M. Panov, S. V. Kutuzov, etc. Kyiv: NTUU "KPI", 2012. 352 p. URL : <https://ela.kpi.ua/handle/123456789/4718>

6. Regularities of the process of high-temperature processing of bulk carbon materials in electric furnaces: monograph / T. V. Lazarev, A. Y. Karvatsky, E. M. Panov, S. V. Stork, A. Y. Pedchenko. Kyiv: NTUU "KPI" "Polytechnic", 2016. 156 p. URL: <https://ela.kpi.ua/handle/123456789/15217>

7. Numerous modeling supersonics with the submenu of the open program code OpenFOAM / A. Y. Karvatsky, I. V. Pulynets, A. Y. Pedchenko, T. V. Lazarev / Space Science and Technology. 2015. Vol. 21, No2. 47-52. URL : http://www.mao.kiev.ua/biblio/journals/knit_all.html

8. Research of interactions seal jump – border layer with supersonic flow of three-dimensional configurations / E. M. Panov, A. Y. Karvatsky, S. V. Leleka, T. V. Lazarev, A. Y. Pedchenko / East European Journal of Advanced Technologies. 2015. № 5/4(77). 4-11. DOI: 10.15587/1729-4061.2015.50911, URL : <http://journals.uran.ua/eejet/article/download/50911/47871>

9. Determination of parameters of the carbon-containing materials gasification process in the rotary kiln cooler drum / A. Karvatskii, T. Lazarev, S. Leleka, I. Mikulionok, O. Ivanenko // Eastern-European Journal of Enterprise Technologies. 2020. Vol. 106. No 4/8. P. 65–76. DOI: 10.15587/1729-4061.2020.210767 URL : <http://journals.uran.ua/eejet/article/view/210767/210939>

10. Mathematical Modeling of Processes and Equipment for the Manufacture of Electrode Carbon Graphite Products / Serhii Leleka, Anton Karvatskii, Ihor Mikulionok, Victor Vytvytskyi & Olena Ivanenko // Design, Simulation, Manufacturing: The Innovation Exchange. DSMIE 2022: Advances in Design, Simulation and Manufacturing V. pp 424–434. URL : https://doi.org/10.1007/978-3-031-06025-0_42

11. Evaluation of the Discrete Element Method for Predicting the Behavior of Granular Media Using Petroleum Coke as an Example / A. Ya. Karvatskii, T. V. Lazarev // Chemical and Petroleum Engineering. 2014. Vol. 50, Nos. 3–4. P. 186–192. URL : <https://link.springer.com/article/10.1007/s10556-014-9877-y>

12. Determining efficient values for the thermophysical properties of bulk materials / Karvatskii A., Panov Ye., Vasylenko G., Vytvytskyi V., Korolenko K. // EasternEuropean Journal of Enterprise Technologies. 2019. Vol. 2. No 5(98). P. 55–62. DOI: 10.15587/1729-4061.2019.164791 URL : <http://journals.uran.ua/eejet/article/view/164791>

13. Karvatskii A.Y. Method of finite elements in problems of mechanics of solid media. Software implementation and visualization of results: teaching. posib. Kyiv: NTUU "KPI" VPI "Polytechnic", 2015. 392 p. URL : <http://ela.kpi.ua/handle/123456789/11636>

14. Karvatskii A. Ya. The current state of the problem of theoretical study of supersonic wrapping of bodies in different configurations / A. Y. Karvatsky / Chemical engineering, ecology and resource saving. 2015. № 1(14). 5-12. URL : <http://chemengine.kpi.ua/article/view/52216/48089>

Information resources on the Internet

1. DSpace STL Igor Sikorsky Kyiv Polytechnic Institute, <https://ela.kpi.ua/handle/123456789/23917>, <https://ela.kpi.ua/handle/123456789/45613>, <https://ela.kpi.ua/handle/123456789/23918>, <http://ela.kpi.ua/handle/123456789/23916>, <https://ela.kpi.ua/handle/123456789/27528>, <http://ela.kpi.ua/handle/123456789/11636>
2. Website: Department of Chemical, Polymeric and Silicate Engineering, <https://cpsm.kpi.ua/metodichni-rozrobki.html>
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:

- providing modern, holistic, interdependent knowledge in the educational component "Applied problems of the mechanics of solid environments", the level of which is determined by the target installation for each specific topic;
- ensuring in the process of lecturing the creative work of students together with the teacher; education of students of professional and business qualities and development of their independent creative thinking;
- formation of the necessary interest in students and providing direction for independent work;
- determination at the current level of development of science in the field of modern methods of mechanics of solid media;
- display of methodological processing of the material (allocation of the main provisions, conclusions, recommendations, clear and adequate to their formulations);
- use for demonstration of visual materials, combining, if possible, them with demonstrating the results of calculations;
- teaching of the educational component materials in a clear and high-quality language in compliance with structural and logical relations, explanation 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 IWS)	Number of hours
Section 1. Mathematical models are based on the Eulerian reference system		
1	Topic 1.1. Models of turbulence <i>Lecture 1. Mathematical models for numerical modeling of turbulent flows. RANS turbulence models. Standard model of turbulence.</i> <i>List of didactic agents:</i> The lecture uses a laptop with an electronic version of the lecture and a projector. Pictures, posters for the lecture. <i>Tasks on the IWS.</i> Formulation of the problem of heat-hydrodynamic state on the basis of the $k - \varepsilon$ turbulence model, taking into account the compressibility of the viscous environment. Initial and boundary conditions. <i>Literature:</i> [1], chapter 11, 256–264. [3], 79–85; [7]; electronic lecture notes.	2
2	<i>Lecture 2. RANS turbulence models. Formulation of the problem of heat-hydrodynamic state on the basis of the turbulence model, taking into account</i>	2

No s/p	The name of the lecture topic and the list of main issues (links to literature and tasks on the IWS)	Number of hours
	the compressibility of the viscous environment. Spalart-Allmaras turbulence model. <u>List of didactic agents:</u> The lecture uses a laptop with an electronic version of the lecture and a projector. Pictures, posters for the lecture. <u>Tasks on the IWS.</u> Models of turbulence and Spalart-Allmaras. Initial and boundary conditions. <u>Literature:</u> [1], chapter 11, 264–267; [7]; [A7], [A8]; electronic lecture notes.	
3	<u>Lecture 3.</u> LES turbulence models. Sub-tank models. Model Smagorinsky-Lilly. Hybrid models of DES turbulence. <u>List of didactic agents:</u> The lecture uses a laptop with an electronic version of the lecture and a projector. Pictures, posters for the lecture. <u>Tasks on the IWS.</u> LES, DES turbulence models. <u>Literature:</u> [1], chapter 11, 267–271; electronic lecture notes.	2
4	Topic 1.2. Patterns of current of reactive environments <u>Lecture 4.</u> Conservation equations for the flow of reactive environments. General provisions. Select source variables. Thermochemistry. Tensor tension. Thermal conductivity and diffusion of reaction components. Chemical kinetics. <u>List of didactic agents:</u> The lecture uses a laptop with an electronic version of the lecture and a projector. Pictures, posters for the lecture. <u>Tasks on the IWS.</u> Conservation equations for the flow of reactive environments. General provisions. <u>Literature:</u> [1], chapter 10, 218–228; [A1]; electronic lecture notes.	2
5	<u>Lecture 5.</u> Conservation equations for the flow of reactive environments. Stechiometry flame pre-mixed mixture of gases. Stechiometry of diffuse flame. Equation of preservation of momentum. Mass preservation equation for reaction components. Diffusion velocity: exact equations and approximations. Binary diffusion. Multicomponent diffusion. <u>List of didactic agents:</u> The lecture uses a laptop with an electronic version of the lecture and a projector. Pictures, posters for the lecture. <u>Tasks on the IWS.</u> Stechiometry flame pre-mixed mixture of gases. Stechiometry of diffuse flame. Equation of preservation of momentum. <u>Literature:</u> [1], chapter 10, 229–234; [A1]; electronic lecture notes.	2
6	<u>Lecture 6.</u> Conservation equations for the flow of reactive environments. Mass preservation equation for combustible mixture and speed correction. Equation of energy conservation. <u>List of didactic agents:</u> The lecture uses a laptop with an electronic version of the lecture and a projector. Pictures, posters for the lecture. <u>Tasks on the IWS.</u> Mass preservation equation for combustible mixture and speed correction. Equation of energy conservation. <u>Literature:</u> [1], chapter 10, 234–242; [A1]; electronic lecture notes.	2
7	<u>Lecture 7.</u> Conservation equations for the flow of reactive environments. Simplified forms of the energy equation. Sustained flame pressure. Equality of heat capacity for all components of the reaction. Constant heat capacity of the mixture. Summary equations of preservation. <u>List of didactic agents:</u> The lecture uses a laptop with an electronic version of the lecture and a projector. Pictures, posters for the lecture. <u>Tasks on the IWS.</u> Sustained flame pressure. Equality of heat capacity for all components of the reaction. Constant heat capacity of the mixture. Summary equations of preservation. <u>Literature:</u> [1], chapter 10, 242–247; [A1]; electronic lecture notes.	2

No s/p	The name of the lecture topic and the list of main issues (links to literature and tasks on the IWS)	Number of hours
8	<u>Lecture 8.</u> Formulation of the problem of the heat-hydrodynamic state of the reacting medium during the combustion of natural gas without preliminary mixing. <u>List of didactic agents:</u> The lecture uses a laptop with an electronic version of the lecture and a projector. Pictures, posters for the lecture. <u>Tasks on the IWS.</u> The problem of the heat-hydrodynamic state of the reacting medium during the combustion of natural gas without preliminary mixing. <u>Literature:</u> [1], chapter 10, 248–253; electronic lecture notes.	2
9	Topic 1.3. Examples of using turbulence models and the flow of reactive medias <u>Lecture 9.</u> Results of numerical modeling by RANS, LES, DES and DNS turbulence models. <u>List of didactic agents:</u> The lecture uses a laptop with an electronic version of the lecture and a projector. Pictures, posters for the lecture. <u>Tasks on the IWS.</u> Analysis and comparison of numerical modeling results by RANS, LES, DES and DNS turbulence models. <u>Literature:</u> [7]; [A1]; [A7–A8]; electronic lecture notes.	2
10	<u>Lecture 10.</u> Results of numerical modeling of reactive media (processes of combustion of solid and gaseous fuels). <u>List of didactic agents:</u> The lecture uses a laptop with an electronic version of the lecture and a projector. Pictures, posters for the lecture. <u>Tasks on the IWS.</u> Analysis and comparison of the results of numerical modeling of reactive media (processes of combustion of solid and gaseous fuels). <u>Literature:</u> [A1]; [A9, A10]; electronic lecture notes.	2
Section 2. Mathematical models are based on the Lagrangian reference system		
11	Topic 2.1. Models of statics, dynamics and heat exchange of bulk materials <u>Lecture 11.</u> Formulation of the problem of a moving layer of bulk material using the discrete element method. Initial and boundary conditions. <u>List of didactic agents:</u> The lecture uses a laptop with an electronic version of the lecture and a projector. Pictures, posters for the lecture. <u>Tasks on the IWS.</u> The problem of a moving layer of bulk material using the discrete element method. Initial and boundary conditions. <u>Literature:</u> [2], chapter 1, p. 7–10; [A11]; electronic lecture notes.	2
12	<u>Lecture 12.</u> Physical and mathematical formulation of the mechanothermic problem for the theoretical determination of the thermophysical properties of bulk materials. Algorithm for solving the problem of theoretical determination of thermophysical properties of bulk materials. <u>List of didactic agents:</u> The lecture uses a laptop with an electronic version of the lecture and a projector. Pictures, posters for the lecture. <u>Tasks on the IWS.</u> Algorithm for solving the problem of theoretical determination of thermophysical properties of bulk materials. <u>Literature:</u> [2], chapter 1, 10–15; [A12]; electronic lecture notes.	2
13	Topic 2.2. Examples of using static models, dynamics and heat exchange of bulk materials <u>Lecture 13.</u> Software products LIGGGHTS and ParaView for modeling physical fields of bulk materials. Source LIGGGHTS script. Rules of processing. An example of a source script. <u>List of didactic agents:</u> The lecture uses a laptop with an electronic version of the lecture and a projector. Pictures, posters for the lecture. <u>Tasks on the IWS.</u> Software products LIGGGHTS and ParaView for modeling	2

No s/p	The name of the lecture topic and the list of main issues (links to literature and tasks on the IWS)	Number of hours
	<i>physical fields of bulk materials. <u>Literature:</u> [2], chapter 3, 26–35; electronic lecture notes.</i>	
14	<i><u>Lecture 14.</u> Visualize the results of the script in the ParaView program. Creating the geometry of the calculated area for the scripts of the program LIGGGHTS. <u>List of didactic agents:</u> The lecture uses a laptop with an electronic version of the lecture and a projector. Pictures, posters for the lecture. <u>Tasks on the IWS.</u> Visualize the results of the script in the ParaView program. Create a geometry of the calculated area for LIGGGHTS scripts. <u>Literature:</u> [2], chapter 4, 37–45, chapter 6, 62–70; electronic lecture notes.</i>	2
15	<i><u>Lecture 15.</u> Examples of using static models, dynamics and heat exchange of bulk materials (LIGGGHTS programs). Drum mill. Screw feeder. Two-turn mixer of continuous action. Determination of effective values of thermophysical properties of bulk material. <u>List of didactic agents:</u> The lecture uses a laptop with an electronic version of the lecture and a projector. Pictures, posters for the lecture. <u>Tasks on the IWS.</u> Examples of using LIGGGHTS. Drum mill. Determination of effective values of thermophysical properties of bulk material. <u>Literature:</u> [2], chapter 5, 46–61; electronic lecture notes.</i>	2
Section 3. Mathematical models are based on continuum-discrete approximation		
16	Topic 3.1. Models of nonisothermic two-phase current (gas – liquid droplets or liquid – particulate matter) <i><u>Lecture 16.</u> Mathematical formulation of the continuum-discrete problem of nonisothermic two-phase current. Initial and boundary conditions. <u>List of didactic agents:</u> The lecture uses a laptop with an electronic version of the lecture and a projector. Pictures, posters for the lecture. <u>Tasks on the IWS.</u> Mathematical formulation of the continuum-discrete problem of nonisothermic two-phase current. Initial and boundary conditions. <u>Literature:</u> [A2]; electronic lecture notes.</i>	2
17	Topic 3.2. Models of solid fuel gasification <i><u>Lecture 17.</u> Mathematical formulation of the problem of gasification of carbon-containing material based on DPM for a mixture of reacting gases, taking into account the turbulent flow mode. Global heterogeneous and homogeneous reactions describing the process of gasification of carbon-containing material. <u>List of didactic agents:</u> The lecture uses a laptop with an electronic version of the lecture and a projector. Pictures, posters for the lecture. <u>Tasks on the IWS.</u> Mathematical formulation of the problem of gasification of carbon-containing material based on DPM for a mixture of reacting gases, taking into account the turbulent flow mode. <u>Literature:</u> [A9, A10]; electronic lecture notes.</i>	2
18	Topic 3.3. Examples of using continuum-discrete models <i><u>Lecture 18.</u> Isothermal two-phase current in the reactor. Gasification of carbon-containing materials particles in the drum-cooler of the rotating furnace. <u>List of didactic agents:</u> The lecture uses a laptop with an electronic version of the lecture and a projector. Pictures, posters for the lecture. <u>Tasks on the IWS.</u> Analysis of the results of numerical modeling of the isothermal two-phase current process in the reactor. Analysis of the results of numerical modeling of the process of gasification of carbon-containing material particles based on DPM for a mixture of reacting gases, taking into account the turbulent flow mode. <u>Literature:</u> [A2]; [A9, A10]; electronic lecture notes.</i>	2
Total		36

Practical classes

The main goals of the cycle of practical classes are the application of theoretical knowledge by students to build numerical models for solving applied problems (problems) of the MCC [1, 2], [A1–A4].

No s/p	The name of the topic of practical classes and the list of main issues (reference to literature and tasks on the IWS)	Number of hours
Section 1. Mathematical models are based on the Eulerian reference system		
1	Topic 1.3. Examples of using turbulence models and the flow of reactive environments Computer workshop 1. Construction of numerical models of RANS turbulence ($k - \varepsilon$) on the example of a heat exchanger pipe in the pipe. <u>List of didactic agents:</u> personal computer (notebook), ANSYS Workbench software products), methodical recommendations. <u>Tasks on the IWS.</u> Examples of building numerical models of RANS turbulence ($k - \varepsilon$), ($k - \omega$). <u>Literature:</u> [1]; ANSYS Workbench [A2].	6
2	Topic 1.3. Examples of using turbulence models and the flow of reactive environments Computer workshop 2. Construction of numerical models of the natural gas combustion process without prior mixing in a rotating furnace, taking into account the $k - \varepsilon$ model of turbulence and radiation heat exchange. <u>List of didactic agents:</u> personal computer (notebook), ANSYS Workbench software products), methodical recommendations. <u>Tasks on the IWS.</u> Examples of constructing numerical models of the natural gas combustion process without prior mixing. <u>Literature:</u> [1]; ANSYS Workbench [A2]; [A10].	4
Section 2. Mathematical models are based on the Lagrangian reference system		
3	Topic 2.2. Examples of using static models, dynamics and heat exchange of bulk materials Computer workshop 3. Construction of numerical models (preparation of screens) dynamics of bulk materials in the drum mill. <u>List of didactic agents:</u> personal computer, software products LIGGGHTS [A3] and ParaView [A4], methodical recommendations. <u>Tasks on the IWS.</u> Examples of building numerical models of dynamics of bulk materials in industrial equipment. <u>Literature:</u> [2]; LIGGGHTS [A3]; ParaView [A4].	6
4	Topic 2.2. Examples of using static models, dynamics and heat exchange of bulk materials Computer workshop 4. Construction of numerical models (preparation of screens) of thermomechanics to determine the effective values of thermophysical properties of bulk material. <u>List of didactic agents:</u> personal computer, software products LIGGGHTS [A3] and ParaView [A4], methodical recommendations. <u>Tasks on the IWS.</u> Examples of constructing numerical models of numerical models of thermo-mechanics to determine the effective values of thermophysical properties of bulk material. <u>Literature:</u> [2]; LIGGGHTS [A3]; ParaView [A4].	6
Section 3. Mathematical models are based on continuum-discrete approximation		
5	Topic 3.3. Examples of using continuum-discrete models	6

No s/p	The name of the topic of practical classes and the list of main issues (reference to literature and tasks on the IWS)	Number of hours
	Computer workshop 5. Construction of numerical models of the isothermal two-phase current process in the reactor, taking into account the turbulence model. <u>List of didactic agents:</u> personal computer (notebook), ANSYS Workbench software products) ¹ , methodical recommendations. <u>Tasks on the IWS.</u> Examples of constructing numerical models of the isothermal two-phase current process in the reactor. Literature: <u>Literature:</u> [1]; ANSYS Workbench [A2].	
6	Topic 3.3. Examples of using continuum-discrete models Computer workshop 6. Construction of numerical models of the process of gasification of carbon-containing material particles based on DPM for a mixture of reacting gases, taking into account the turbulent flow mode (model) and radiation heat exchange. <u>List of didactic agents:</u> personal computer (notebook), ANSYS Workbench software products) ¹ , methodical recommendations. <u>Tasks on the IWS.</u> Examples of constructing numerical models of the process of gasification of carbon-containing material particles based on DPM for a mixture of reacting gases, taking into account the turbulent mode of flow and radiation heat exchange. Literature: <u>Literature:</u> [1]; ANSYS Workbench [A2]; [A9].	6
7	MCW	2
Total		36

Seminars

According to the working curriculum, seminars are not provided.

Laboratory classes

The working curriculum does not include laboratory classes.

6. Independent work of the student

No s/p	Name of the topic submitted for self-study	Number of hours of IWS
Section 1. Mathematical models are based on the Eulerian reference system		
1	Topic 1.1. Models of turbulence Mathematical models for numerical modeling of turbulent flows. RANS turbulence models. Standard $k - \varepsilon$ model of turbulence. Formulation of the problem of heat-hydrodynamic state on the basis $k - \varepsilon$ of the turbulence model, taking into account the compressibility of the viscous environment. Initial and boundary conditions. Literature: [1], chapter 11, 256–264. [3], 79–85; [7]; electronic lecture summary. RANS turbulence models. Formulation of the problem of heat-hydrodynamic state on the basis $k - \omega$ of the turbulence model, taking into account the compressibility of the viscous environment. Spalart-Allmaras turbulence model. Literature: [1], chapter 11, 264–267; [7]; [A7], [A8]; electronic lecture summary. Les turbulence models. Sub-tank models. Model Smagorinsky-Lilly. Hybrid models of DES turbulence. <u>Literature:</u> [1], chapter 11, 267–271; electronic lecture summary.	5
2	Topic 1.2. Patterns of current of reactive environments	5

¹ To perform calculations at ANSYS Workbench, ANSYS Fluent students use student licenses.

No s/p	Name of the topic submitted for self-study	Number of hours of IWS
	<i>Conservation equations for the flow of reactive environments. General provisions. Select source variables. Thermochemistry. Tensor tension. Thermal conductivity and diffusion of reaction components. Chemical kinetics.</i> <i>Literature: [1], chapter 10, 218–228; [A1]; electronic lecture notes.</i> <i>Conservation equations for the flow of reactive environments. Stehiometry flame pre-mixed mixture of gases. Stechiometry of diffuse flame. Equation of preservation of momentum. Mass preservation equation for reaction components. Diffusion velocity: exact equations and approximations. Binary diffusion. Multicomponent diffusion.</i> <i>Literature: [1], chapter 10, 229–234; [A1]; electronic lecture summary.</i> <i>Conservation equations for the flow of reactive environments. Mass preservation equation for combustible mixture and speed correction. Equation of energy conservation.</i> <i>Literature: [1], chapter 10, 234–242; [A1]; electronic lecture notes.</i> <i>Conservation equations for the flow of reactive environments. Simplified forms of the energy equation. Sustained flame pressure. Equality of heat capacity for all components of the reaction. Constant heat capacity of the mixture. Summary equations of preservation.</i> <i>Literature: [1], chapter 10, 242–247; [A1]; electronic lecture notes.</i> <i>Formulation of the problem of the heat-hydrodynamic state of the reacting medium during the combustion of natural gas without preliminary mixing.</i> <i>Literature: [1], chapter 10, 248–253; electronic lecture notes.</i>	
3	Topic 1.3. Examples of using turbulence models and the flow of reactive environments <i>Results of numerical modeling by RANS, LES, DES and DNS turbulence models. Analysis and comparison of numerical modeling results.</i> <i>Literature: [7]; [A1]; [A7–A8]; electronic lecture summary.</i> <i>Results of numerical modeling of reactive media (processes of combustion of solid and gaseous fuels). Analysis and comparison of numerical modeling results.</i> <i>Literature: [A1]; [A9, A10]; electronic lecture notes.</i>	5
Section 2. Mathematical models are based on the Lagrangian reference system		
4	Topic 2.1. Models of statics, dynamics and heat exchange of bulk materials <i>Formulation of the problem of a moving layer of bulk material using the discrete element method. Initial and boundary conditions.</i> <i>Literature: [2], chapter 1, p. 7–10; [A11]; electronic lecture summary.</i> <i>Physical and mathematical formulation of the mechanothermic problem for the theoretical determination of the thermophysical properties of bulk materials. Algorithm for solving the problem of theoretical determination of thermophysical properties of bulk materials.</i> <i>Literature: [2], chapter 1, 10–15; [A12]; electronic lecture notes.</i>	5
5	Topic 2.2. Examples of using static models, dynamics and heat exchange of bulk materials <i>Software products LIGGGHTS and ParaView for modeling physical fields of bulk materials. Source LIGGGHTS script. Rules of processing. An example of a source script.</i> <i>Literature: [2], chapter 3, 26–35; electronic lecture notes.</i>	5

No s/p	Name of the topic submitted for self-study	Number of hours of IWS
	Visualize the results of the script in the ParaView program. Create a geometry of the calculated area for LIGGGHTS scripts. Create a geometry of the calculated area for LIGGGHTS scripts. <i>Literature:</i> [2], chapter 4, 37–45, chapter 6, 62–70; electronic lecture notes.	
6	Topic 2.2. Examples of using static models, dynamics and heat exchange of bulk materials <i>Examples of using static models, dynamics and heat exchange of bulk materials (LIGGGHTS programs). Drum mill. Screw feeder. Two-turn mixer of continuous action. Determination of effective values of thermophysical properties of bulk material. Literature:</i> [2], chapter 5, 46–61; electronic lecture notes.	5
Section 3. Mathematical models are based on continuum-discrete approximation		
7	Topic 3.1. Models of nonisothermic two-phase flow (gas – liquid drops or liquid – particulate matter). <i>Mathematical formulation of the continuum-discrete problem of nonisothermic two-phase current. Initial and boundary conditions. Literature:</i> [A2]; electronic lecture notes.	6
8	Topic 3.2. Models of solid fuel gasification <i>Mathematical formulation of the problem of gasification of carbon-containing material based on DPM for a mixture of reacting gases, taking into account the turbulent flow mode. Global heterogeneous and homogeneous reactions describing the process of gasification of carbon-containing material. Literature:</i> [A9, A10]; electronic lecture notes.	5
9	Topic 3.3. Examples of using continuum-discrete models <i>Isothermal two-phase current in the reactor. Gasification of carbon-containing materials particles in the drum-cooler of the rotating furnace. Analysis of the results of numerical modeling of the isothermal two-phase current process in the reactor. Analysis of the results of numerical modeling of the process of gasification of carbon-containing material particles based on DPM for a mixture of reacting gases, taking into account the turbulent flow mode. Literature:</i> [A2]; [A9, A10]; electronic lecture notes.	3
10	MCW	4
11	Exam	30
Total		78

Individual tasks

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

Control works

The purpose of modular control work:

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

The curriculum of the educational component provides for one modular control work, which covers sections 1 and 2. An approximate list of questions to the MCW is given at the end of Syllabus. The wording of questions to the MCW may be slightly changed in accordance with the peculiarities of teaching lecture

material and the perception of it by students. In order to prepare students in SRS mode, the teacher introduces them to mcw questions 1-2 weeks before the work. A package of tasks for MCW has been developed.

Politics and control

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 active participation in lectures, preparation of scientific publications on 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.	Ind.less.	IWS	MCW	CGW	Semester certification
2	5	150	36	36	–	–	78	1	–	Exam

Current control: reports on laboratory work (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: exam.

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

- 1) execution of computer workshops in laboratory classes (6 in total);
- 2) modular control work;
- 3) answer to the exam (in writing).

System of rating (weight) points and evaluation criteria

1. Laboratory classes (computer workshops):

- "excellent", creative performance of the task, fluency in the material – 4-5 points;
- "good", complete the task in full, but with minor errors – 3 points;
- "satisfactory", completing the task with individual errors – 2 points;
- "unsatisfactory", non-fulfillment of the task – 0 points.

2. Modular control work:

- "excellent", full answer (at least 90% of the necessary information) – 18-20 points;
- "good", a sufficiently complete answer (at least 75% of the necessary information), or a full answer with minor inaccuracies – 15-17 points;
- "satisfactory", incomplete response (at least 60% of the necessary information) and minor errors – 12-14 points;
- "unsatisfactory", unsatisfactory answer – 0 points.

2. 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.
3. The maximum amount of points of the starting component is 50. A prerequisite for admission to the exam is the enrollment of all tasks of practical classes and the delivery of settlement work and a starting rating of at least 25 points.
4. According to the results of educational work for the first 7 weeks, the "ideal student" should score 25 points. At the certification (8th week), the student receives "enrolled" if his current rating is not less than 12 points.
5. According to the results of 15 weeks, the "ideal student" should score 50 points. At the second certification (14th week), the student receives "enrolled" if his current rating is not less than 25 points.
6. The maximum amount of points for semester R is 50 (where $R = r_{lab} \cdot 6 + r_{mkp} = 5 \cdot 6 + 20 = 30 + 20 = 50$).

At the exam, students perform written control work. Each task contains two theoretical questions. The list of questions is given in the methodological recommendations for the assimilation of the credit module. Each theoretical question is estimated at 25 points.

System of evaluation of theoretical questions:

- "excellent", full answer (at least 90% of the necessary information) – 23-25 points;
- "good", a sufficiently complete answer (at least 75% of the necessary information or minor inaccuracies) – 19-22 points;
- "satisfactory", incomplete answer (at least 60% of the necessary information and some errors) – 15-21 points;
- "unsatisfactory", unsatisfactory answer – 0 points.

The maximum rating of examination control work is

$$r_E = r_{T1} + r_{T2} = 25 + 25 = 50 \text{ points.}$$

Terms of admission to semester control: semester rating of at least 25 points.

The amount of starting points and points for examination control work is transferred to the examination 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 (educational component)

List of questions submitted for semester control

Theoretical questions

1. Describe three main groups of mathematical models to describe turbulent flows.
2. Analyze what is the center of physical quantities according to Reynolds and Favre?.
3. Describe the RANS differential equation system.
4. Analyze the main classical approaches to assess turbulent viscosity.
5. Analyze what is the difference between determining the tensor of total stresses and the vector of full heat flow in RANS and LES models?
6. Analyze the scalar equations of the standard $k - \varepsilon$ turbulence model.
7. Analyze the scalar equations of the $k - \omega$ turbulence model.
8. Analyze the formulation of the problem of heat-hydrodynamic state on the basis $k - \varepsilon$ of the turbulence model, taking into account the compressibility of the viscous environment.
9. Analyze the formulation of the problem of heat-hydrodynamic state on the basis $k - \omega$ of the turbulence model, taking into account the compressibility of the viscous environment.
10. Describe the Spalart-Allmaras turbulence model.
11. Analyze LES turbulence models and give them a description.
12. Analyze what causes the need for subsite models?
13. Describe the model Smagorinsky-Lilly.
14. Describe hybrid models of DES turbulence.
15. Analyze what differences the conservation equations have for reacting flows compared to the usual Navier-Stokes equations for non-reactive environments?
16. Describe the phenomenon of the combustion process.
17. Describe the mass fraction of the component of chemical reactions.

18. Analyze the characteristics of the reacting flow of the compressive medium.
19. Analyze what equations make up the MC system of differential equations for the flow of the reacting environment and what determines their number?
20. Describe the definition of full and partial pressure.
21. Describe the definition of the density of multicomponent gas.
22. Analyze the determination of the concentration of components of chemical reactions through the molar lobe and molar concentration.
23. Analyze the forms of energy and enthalpia for reacting flows.
24. Describe the determination of the heat capacity of the particle of components of reacting flows. What is standard enthalpy?
25. Analyze the formulas for complete entalpy and its components.
26. Analyze the relationship between h_{sk} and e_{sk} .
27. Describe the definition of energy and enthalpia for a mixture of N components.
28. Describe forms of energy and enthalpia to record conservation equations.
29. Analyze how mass isohorn and isobaric heat capacity of a mixture of gases are determined?
30. Describe the definition of a tensor of viscous tension.
31. Analyze the essence of the phenomena of thermal conductivity and diffusion of reaction components.
32. Describe the laws of Fourier and Fika. Analyze the physical content of thermal conductivity and molecular diffusion coefficients.
33. Analyze the physical content of the Levis number.
34. Analyze Prandtl's number, its physical content.
35. Analyze what Schmidt's number and his connection to Prandtl and Levis numbers mean?
36. Describe chemical kinetics.
37. Analyze the mass preservation equation for the N components of the reaction.
38. Describe the definition for reaction velocity constants.
39. Analyze what the full mathematical formulation of the interaction of streams implies?
40. Analyze the configurations of the diffuse flame and with preliminary mixing.
41. Describe the stehiometry of the flame of a pre-mixed mixture of gases.
42. Analyze the methods to determine the equivalent ratio of the mixture of gases.
43. Analyze the formula to determine the mass stechometric ratio.
44. Describe the definition of the equivalent ratio of the mixture of gases. Analyze the rich and poor mix.
45. Analyze the formula to determine the mass fraction of fuel in the mixture.
46. Analyze the stehiometry of the diffuse flame.
47. Describe the equation of conservation of momentum for reaction media.
48. Describe the equation of mass preservation for the components of reactions.
49. Analyze the determination of the diffusion rate using accurate and approximate equations. What is the Sori effect?
50. Analyze what characterizes binary and multicomponent diffusion? Describe Hirschfelder's approach?
51. Analyze the mass preservation equation for the combustible mixture and speed correction.
52. Analyze the conservation equation for total energy.
53. Describe the definition of the energy flow vector.
54. Analyze the retention equation for complete enthalpia.
55. Analyze the conservation equation for explicit or non-isothermal enthalpy.
56. Analyze the conservation equation for explicit or non-isothermal energy.
57. Analyze the entalpic and energy forms and the corresponding equations of energy.
58. Analyze the simplified forms of the energy equation.
59. Describe the case of sustained flame pressure.
60. Describe the case of equality of heat capacity for all components of the reaction.
61. Describe the case of constant heat capacity of the mixture.
62. Analyze the final retention equations.

63. Analyze the mathematical formulation of the problem of the heat-hydrodynamic state of the reacting medium during the combustion of natural gas without preliminary mixing.
64. Analyze what is the main difference between discrete and continuual representation of the movement of the environment?
65. Analyze the formulation of the problem of the moving layer of bulk material using the discrete element (DEM) method.
66. Describe the initial and boundary conditions of the system of equations of balance of mechanical motion of a particle of bulk material.
67. Describe the physical formulation of a mechanothermic problem for the theoretical determination of the thermophysical properties of bulk materials.
68. Analyze the mathematical formulation of the mechanothermic problem for the theoretical determination of the thermophysical properties of bulk materials.
69. Analyze the algorithm for solving the problem of theoretical determination of thermophysical properties of bulk materials.
70. Analyze what software is needed to perform statics modeling and bulk environment dynamics? Describe its purpose and give the main characteristics.
71. Describe the general rules for the development of the LIGGGHTS script.
72. Describe the interface of the ParaView program, describe its main menu groups.
73. Analyze the structure and commands of the script file to simulate the movement of loose material granules in the drum mill.
74. Analyze the structure and commands of the script file to simulate the movement of polymer granules in the screw feeder.
75. Analyze the structure and commands of the script file to simulate the movement of loose material particles in a two-sided continuous action mixer.
76. Analyze and compare the results of modeling the thermophysical properties of bulk materials with mono- and polydispersed composition.
77. Describe the procedure for preparing geometry files of the calculated area for use in LIGGGHTS scripts.
78. Describe the initial and boundary conditions of the continuum-discrete problem of the nonisothermic two-phase current.
79. Describe the mathematical formulation of the continuum-discrete problem of the nonisothermic two-phase current (liquid – particulate matter).
80. Analyze the mathematical formulation of the DPM-based carbon-containing material gasification problem for a mixture of reacting gases, taking into account the turbulent flow mode.
81. Analyze global heterogeneous and homogeneous reactions describing the process of gasification of carbon-containing material.
82. Analyze the results of numerical modeling of the isothermal two-phase current in the reactor.
83. Analyze the results of numerical modeling of the carbon-containing material gasification process based on DPM for a mixture of reacting gases, taking into account the turbulent flow mode.

List of issues and tasks submitted for modular control work

1. Analyze what characterizes binary and multicomponent diffusion? Describe Hirschfelder's approach?
2. Analyze the mass preservation equation for the combustible mixture and speed correction.
3. Analyze the conservation equation for total energy.
4. Describe the definition of the energy flow vector.
5. Analyze the retention equation for complete enthalpia.
6. Analyze the conservation equation for explicit or non-isothermal enthalpy.
7. Analyze the conservation equation for explicit or non-isothermal energy.
8. Analyze the entalpic and energy forms and the corresponding equations of energy.
9. Analyze the simplified forms of the energy equation.
10. Describe the case of sustained flame pressure.

11. Describe the case of equality of heat capacity for all components of the reaction.
12. Describe three main groups of mathematical models to describe turbulent flows.
13. Analyze what is the center of physical quantities according to Reynolds and Favre?.
14. Describe the RANS differential equation system.
15. Analyze the main classical approaches to assess turbulent viscosity.
16. Analyze what is the difference between determining the tensor of total stresses and the vector of full heat flow in RANS and LES models?
17. Analyze the scalar equations of the standard $k - \varepsilon$ turbulence model.
18. Analyze the scalar equations of the $k - \omega$ turbulence model.
19. Analyze the formulation of the problem of heat-hydrodynamic state on the basis $k - \varepsilon$ of the turbulence model, taking into account the compressibility of the viscous environment.
20. Analyze the formulation of the problem of heat-hydrodynamic state on the basis $k - \omega$ of the turbulence model, taking into account the compressibility of the viscous environment.
21. Describe the Spalart-Allmaras turbulence model.
22. Analyze what differences the conservation equations have for reacting flows compared to the usual Navier-Stokes equations for non-reactive medias?
23. Describe the phenomenon of the combustion process.
24. Describe the mass fraction of the component of chemical reactions.
25. Analyze the characteristics of the reacting flow of the compressive medium.
26. Analyze what equations make up the MC system of differential equations for the flow of the reacting environment and what determines their number?
27. Describe the definition of full and partial pressure.
28. Describe the definition of the density of multicomponent gas.
29. Analyze the determination of the concentration of components of chemical reactions through the molar lobe and molar concentration.
30. Analyze the forms of energy and enthalpia for reacting flows.
31. Describe the determination of the heat capacity of the particle of components of reacting flows. What is standard enthalpy?
32. Analyze the formulas for complete entalpy and its components.
33. Analyze the essence of the phenomena of thermal conductivity and diffusion of reaction components.
34. Describe the laws of Fourier and Fika. Analyze the physical content of thermal conductivity and molecular diffusion coefficients.
35. Analyze the physical content of the Levis number.
36. Analyze Prandtl's number, its physical content.
37. Analyze what Schmidt's number and his connection to prandtl and Levis numbers mean?
38. Describe chemical kinetics.
39. Analyze the mass preservation equation for the N components of the reaction.
40. Describe the definition for reaction velocity constants.
41. Analyze what the full mathematical formulation of the interaction of streams implies?
42. Analyze the configurations of the diffuse flame and with preliminary mixing.
43. Describe the stehiometry of the flame of a pre-mixed mixture of gases.
44. Analyze the formulation of the problem of a moving layer of bulk material using the discrete element (DEM) method.
45. Describe the initial and boundary conditions of the system of equations of balance of mechanical motion of a particle of bulk material.
46. Describe the physical formulation of a mechanothermic problem for the theoretical determination of the thermophysical properties of bulk materials.
47. Analyze the mathematical formulation of the mechanothermic problem for the theoretical determination of the thermophysical properties of bulk materials.
48. Analyze the algorithm for solving the problem of theoretical determination of thermophysical properties of bulk materials.

49. *Analyze what software is needed to perform statics modeling and bulk environment dynamics? Describe its purpose and give the main characteristics.*
50. *Describe the general rules for the development of the LIGGGHTS script.*
51. *Describe the interface of the ParaView program, describe its main menu groups.*
52. *Analyze the structure and commands of the script file to simulate the movement of loose material granules in the drum mill.*
53. *Analyze the structure and commands of the script file to simulate the movement of polymer granules in the screw feeder.*
54. *Analyze the structure and commands of the script file to simulate the movement of loose material particles in a two-sided continuous action mixer.*
55. *Describe the initial and boundary conditions of the continuum-discrete problem of the nonisothermal two-phase current.*
56. *Describe the mathematical formulation of the continuum-discrete problem of the nonisothermal two-phase current (liquid – particulate matter).*
57. *Analyze the mathematical formulation of the DPM-based carbon-containing material gasification problem for a mixture of reacting gases, taking into account the turbulent flow mode.*
58. *Analyze global heterogeneous and homogeneous reactions describing the process of gasification of carbon-containing material.*
59. *Analyze the results of numerical modeling of the isothermal two-phase current in the reactor.*
60. *Analyze the results of numerical modeling of the carbon-containing material gasification process based on DPM for a mixture of reacting gases, taking into account the turbulent flow mode.*

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 25.06.2025)