



Heat transfer

Work program of the educational component (Syllabus)

Details of the educational component

Field of Knowledge	<i>First (Bachelor's)</i>
Speciality	<i>13 Mechanical Engineering</i>
Educational program	<i>131 Applied Mechanics</i>
Status of the educational component	<i>OPP Packaging and Packaging Equipment Engineering</i>
Form of study	<i>Custom</i>
Year of preparation, semester	<i>full-time (full-time)</i>
Scope of the educational component	<i>3rd year, spring semester</i>
	<i>4(120)</i>
Semester control / control measures	<i>Passed</i>
Class schedule	<i>4 hours per week (2 hours of lectures, 1 hour of practical classes, 1 hour of laboratory classes)</i>
Language of instruction	<i>Ukrainian</i>
Information about the course leader / teachers	Lecturer: Associate Professor, Ph.D. SHYLOVYCH Tetiana Borysivna, https://cpsm.kpi.ua/shilovich-tetyana-borisivna.html?tmpl=component Practical, Laboratory: https://cpsm.kpi.ua/shilovich-tetyana-borisivna.html?tmpl=component Associate Professor, Ph.D. KAZAK Iryna Oleksandrivna, https://cpsm.kpi.ua/kazak-irina-oleksandrivna.html?tmpl=component
Course placement	<i>Sikorsky Platform: https://do.ipk.kpi.ua/course/view.php?id=3251</i>

Program of the educational component

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

Most of the technological processes of enterprises for the production of packaging materials and products are associated with heat transfer, and, in many cases, this operation is the final stage of technological processing, which determines the properties of materials and product quality. The rational choice of the heat treatment mode and the corresponding heat exchange equipment determines the technological and operational characteristics of materials and products, resource and energy saving, as well as economic indicators of production.

There are three fundamentally different in their physical essence ways of heat propagation: thermal conduction (conduction) – heat transfer due to chaotic (thermal) movement of microparticles (molecules – in gases and droplet liquids, oscillation of atoms – in crystal lattices of solids, diffusion of free electrons – in metals), when they come into direct contact with each other; Convection is the transfer of heat due to the movement and mixing of macroscopic volumes of a liquid or gas, that is, the movement of a liquid medium as such. Distinguish between free and forced convection; and thermal radiation – the transfer of energy using electromagnetic waves of the infrared part of the radiation spectrum. All bodies are capable

of emitting energy, while the internal energy of the body is converted into radial energy, which is absorbed by other bodies, again turning into internal energy. This type of heat exchange is possible between bodies of different states of aggregation, both distant from each other and tangential.

In manufacturing, heat transfer processes are carried out in devices called heat exchangers. In real heat exchangers, heat exchange is carried out not by any of these methods, but in a combined way, and in different parts of the apparatus the combination of these methods may be different. For example, in furnaces, heat from flue gases to the surface of burned products is transferred by all types of transfer - thermal radiation, convection and thermal conduction.

In the theory of heat transfer, two processes of heat transfer are distinguished: heat transfer and heat transfer. Heat transfer is the process of heat exchange between a solid body (for example, the wall of an apparatus) and a liquid or gas in contact with it. The process of heat exchange between two liquids, gases, between a liquid and a gas (hot and cold coolants) separated by a solid wall, is called heat transfer. Thus, the heat transfer process consists of the process of heat transfer from a warmer coolant to the wall, thermal conductivity through a solid wall, and heat transfer from the wall to a colder coolant.

The subject of the educational component "Heat transfer" is the processes of heat transfer in devices and devices of polymer and construction industries, calculations of the parameters of these processes.

The solution of this problem is determined by the level of training of specialists working in the field of packaging and packaging equipment engineering.

To successfully solve the problems of calculating heat transfer processes, specialists must be fluent in information, be able to solve the problem of heat transfer in industrial equipment.

The purpose of the educational component "Heat transfer"

The purpose of studying this **educational component** is to form a complex of knowledge in students in the field of heat exchange laws and heat exchange equipment, a set of skills and abilities necessary to carry out thermal and parametric calculations of heat exchange equipment using appropriate methods and reference data. In accordance with the goal, the training of bachelors in this specialty in the discipline requires strengthening the formation of the following competencies in bachelors:

Integral competence:

- the ability to solve complex specialized problems and practical problems in applied mechanics or in the learning process, which involves the application of certain theories and methods of mechanical engineering and is characterized by complexity and uncertainty of conditions.;
- the ability to analyze materials, structures and processes based on the laws, theories and methods of mathematics, natural sciences and applied mechanics (FC1).
- Ability to assess the parameters of operability of materials, structures and machines under operating conditions and find appropriate solutions to ensure a given level of reliability of structures and processes, including in the presence of some uncertainty (FC2).
- the ability to describe and classify a wide range of technical objects and processes, based on a deep knowledge and understanding of basic mechanical theories and practices, as well as basic knowledge of related sciences (FC10).

According to the requirements **of the program of the educational component "Heat Transfer"**, students after mastering it must demonstrate the following program learning outcomes:

- use knowledge of the theoretical foundations of the mechanics of liquids and gases, heat engineering and electrical engineering to solve professional problems (PH02);
- know and understand related fields (mechanics of liquids and gases, heat engineering, electrical engineering, electronics) and be able to identify interdisciplinary connections of applied mechanics at the level necessary to fulfill other requirements of the educational program (PH09);

- to carry out the optimal selection of equipment and the complete set of technical complexes (PH14).

2. Pre-requisites and post-requisites of the educational component (place in the structural and logical scheme of education according to the relevant educational program)

The study of the educational component "Heat Transfer" is based on the principles of integration of various knowledge obtained by students during the first years of bachelor's degree in the study of educational components "Informatics", "Mathematics", "Physics", "Theoretical Foundations of Heat Engineering". The discipline "Heat Transfer" is an educational component of professional training, which should provide solutions to complex problems in the field of engineering, rational use of material and energy resources.

3. Content of the educational component

Chapter 1. Entry

Topic 1. Basic concepts and objectives of the course.

Chapter 2. Thermal conductivity

Topic 2. The basic law of thermal conductivity. Differential equation of thermal conductivity. Thermal conductivity through a single-layer flat wall.

Topic 3. Thermal conductivity through multilayer flat wall. Thermal conductivity of single-layer and multilayer cylindrical wall, spherical wall.

Chapter 3. Convective heat transfer

Topic 4. The theory of similarity as a theory of experiment. The theory of dimensions. Criterion equations.

Topic 5. Convective heat transfer. Free convection.

Topic 6. Forced convection. Current in the canal. Transverse flow around surfaces. Flowing around a single pipe on a "bundle" of pipes. Calculation formulas. Methods of their use. Calculations of heat transfer of the "bundle" of pipes. Insulation. Critical diameter of thermal insulation.

Chapter 4. Thermal radiation

Topic 7. Basic laws of radiation. Radiation intensity. Heat exchange of radiation between solids. Basic calculation formulas and methods of their use. Degree of blackness.

Topic 8. Radiant heat transfer in gases. Physics of the process, heat exchange between solid and gas. Basic calculated ratios. Intensification of the radiant heat transfer process.

Chapter 5. Heat transfer when changing the physical state of matter

Topic 9. Heat transfer during steam condensation.

Topic 10. Heat transfer during the boiling of a liquid.

Chapter 6. Heat transfer and heat exchange equipment

Topic 11. Heat transfer.

Topic 12. General purpose heat exchangers. Verification calculation. Heat transfer in devices for processing plastics, for the production of building materials.

Chapter 7. Heat and mass transfer.

Topic 13. Drying materials.

Topic 14. Theoretical dryer. Air drying with recirculation. The kinetics of the drying process are "drying curve".

Chapter 8. Non-stationary heat transfer

Topic 15. Non-stationary heat transfer. The basic equation of non-stationary thermal conductivity.

Cooling (heating) the plate. Analysis of the resulting solution. The amount of heat given off by the plate.

Topic 16. Cooling of an "infinite" cylinder. Equations. Boundary conditions of the third kind. Solution analysis. The amount of heat that the cylinder gives off during cooling.

Topic 17. Regular cooling mode. Kondratiev's theorems. Approximate methods for calculating thermal conductivity problems.

4. Training materials and resources

Basic literature

1. Kovalenko I.V., Malinovskiy V.V. *Osnovnye protsessy, mashiny i apparaty khimichnykh proizvodstvo: podruch.* – Kyiv: Inres, Volya, 2006. – 261 p.
2. Konstantinov S.M. *Heat and Mass Transfer: Textbook.* -K. VPI: "Polytechnic": Inres. – 2005. -304 p.
3. *Heat transfer: Practicum on educational discipline [Electronic resource]: study. Manual. for students studying under the bachelor's training program in the specialties 131 – "Applied Mechanics" and 133 – "Industrial Engineering" / KPI. Igor Sikorsky; compiled by: T.B. Shilovych – Electronic text data (1 file: 1.2 MB).* – Kyiv: KPI. Igor Sikorsky, 2023. – 39 p. Vulture provided by the Methodological Council of KPI. Igor Sikorsky (Minutes No. 1 dated 07.09.2023) at the request of the Academic Council of the Faculty of Engineering and Chemistry (Minutes No. 5 dated 24.04.2023) <https://ela.kpi.ua/handle/123456789/60989>
4. *Heat transfer: Laboratory practicum on educational discipline [Electronic resource]: study. Manual. for students studying under the bachelor's training program in the specialty 131 - Applied Mechanics and 133 - Industrial Engineering / Igor Sikorsky Kyiv Polytechnic Institute. Igor Sikorsky; compiled by: T.B. Shylovykh, I.O. Kazak – Electronic text data (1 file: 17 MB).* – Kyiv: KPI. Igor Sikorsky, 2022. – 63 p. <https://ela.kpi.ua/handle/123456789/48799>

Further reading

5. John H. Lienhard IV and John H. Lienhard V. *A Heat Transfer Textbook Access Mode* <https://ahtt.mit.edu/wp-content/uploads/2019/08/AHTTv500.pdf> -696

Information resources on the Internet

6. Vernadsky National Library Access mode <http://www.nbuv.gov.ua>
7. Journal "Industrial Heat Engineering" Access mode <http://dspace.nbuv.gov.ua/handle/123456789/209>

5. Methods of mastering the educational component

Lectures

Lectures are aimed at:

- providing modern, holistic, interdependent knowledge on the educational component "Heat transfer", the level of which is determined by the target setting for each specific topic;
- ensuring the creative work of students together with the teacher during the lecture;
- education of students' professional and business qualities and the development of independent creative thinking;
- formation of students' necessary interest and provision of direction for independent work;
- determination at the current level of development of science in the field of modern methods and processes of heat transfer;
- reflection of methodological processing of the material (highlighting the main provisions, conclusions, recommendations, clear and adequate to their formulation);
- use of visual materials for demonstration, combining, if possible, them with the demonstration of results and samples;
- presentation of research materials in a clear and high-quality language in compliance with structural and logical connections, explanation of all newly introduced terms and concepts;
- accessibility for perception by this audience.

No. s/p	Title of the topic of the lecture and a list of main questions (list of didactic tools, references to literature and tasks on the SRS)	Hours
1	Basic concepts and objectives of the course. Entry. Course objectives. The role and place of thermal processes in the calculations of machines and devices of the chemical industry. The science of heat transfer, its theoretical basis. The current state of heat transfer science. Achievements of domestic science. Bibliography: [1] p. 107. Tasks on the SRS. To determine the achievements of domestic science in the field of heat and mass transfer	2
2	The basic law of thermal conductivity. Differential equation of thermal conductivity. Thermal conductivity through a single-layer flat wall. Thermal conductivity. Basic concepts. Temperature gradient. Heat flow. Isothermal surfaces. The basic law of thermal conductivity. Thermal conductivity coefficient. Differential equation of thermal conductivity. Thermal conductivity through a single-layer flat wall. References: [1] p. 107-112. Tasks on the SRS. To study the main provisions of the Fourier hypothesis.	2
3	Thermal conductivity through a multilayer flat wall. Thermal conductivity of a single-layer and multilayer cylindrical wall, spherical wall. Thermal conductivity through a cylindrical and spherical wall. Determination of heat flow, temperature between layers. Total and specific heat flux. Thermal conductivity of single-layer and multilayer cylindrical wall. Specific heat flux, temperature on the contact surfaces between layers. An approximate method for calculating thermal conductivity through single-layer and multilayer cylindrical walls. Bibliography: [1] p. 113-115. Tasks on the SRS. Work out the conditions of unambiguity.	2
4	The theory of similarity as a theory of experiment. Dimension theory. Criterion equations.	2

	<i>Basic concepts of the theory of similarity. Three theorems of similarity. Dimension theory.</i> <i>Bibliography: [1] p. 116-120.</i> <i>Tasks on the SRS. Work out similarity theorems.</i>	
5	Convective heat transfer. Free convection. <i>Basic concepts and types of convective heat transfer. Differential equations. Obtaining criteria for convective heat transfer. References: [1] p.120-124</i> <i>Tasks on the SRS. To work out the calculation of similarity criteria in the natural movement of the liquid. [5].</i>	2
6	Forced convection. <i>Current in the canal. Transverse flow around surfaces. Flowing around a single pipe on a "bundle" of pipes. Calculation formulas. Methods of their use. Calculations of heat transfer of the "bundle" of pipes. Insulation. Critical diameter of thermal insulation.</i> <i>Corrections to the calculation of heat transfer intensity. Transverse, flow around the pipe and the "bundle" of pipes.</i> <i>References: [1] p.105-107.</i> <i>Tasks on the SRS. To work out corrections in the calculation of non-circular channel cross-sections.</i>	2
7	Basic laws of radiation. Radiation intensity. Heat exchange of radiation between solids. Basic calculation formulas and methods of their use. Degree of blackness. <i>Basic concepts and definitions. Laws of radiant heat transfer. References: [1] p.140-142</i> <i>Tasks on the SRS. To work out the method for calculating heat transfer by radiation</i>	2
8	Radiant heat transfer in gases. Physics of the process, heat exchange between solid and gas. Basic calculated ratios. Intensification of the radiant heat transfer process. <i>Heat exchange between solids separated by a transparent medium. Heat exchange by radiation in the presence of screens.</i> <i>References: [1] p.143-144</i> <i>Tasks on the SRS. To work out the method for calculating the heat transfer of radiation with screens.</i>	2
9	Heat transfer during steam condensation. <i>Heat transfer when the physical state of a substance changes. Physics of the process. The main features of the process. Classification of heat transfer cases when the physical state of a substance changes. Heat transfer during steam condensation. Basic patterns. Differential equations of the process. Theoretical solutions to the condensation problem. Solution of the heat transfer problem during condensation based on the theory of similarity. Criterion equations. Methods of their use. Features of the condensation process. Process intensification.</i> <i>References: [1] p.106-107.</i> <i>Tasks on the SRS. To work out the calculation of similarity criteria when solving condensation problems.</i>	2
10	Heat transfer during the boiling of a liquid.	2

	<i>Heat transfer during the boiling of a liquid. Physics of the process. Basic patterns. Film and bubble boiling process. Criterion equations. Methods of their use. Boiling in large volume and in pipes.</i> <i>References: [1] p.109-111.</i> <i>Tasks on the SRS. To work out the method for calculating heat transfer during boiling.</i>	
11	Heat transfer. <i>Radiation-convective heat transfer through flat and cylindrical walls. References: [6] p.120-123.</i> <i>Schemes of the flow of the coolant. Determination of the average temperature difference of coolants. References: [1] p.145-149.</i> <i>Tasks on the SRS. To work out the method for calculating the logarithmic mean temperature head.</i>	2
12	General purpose heat exchangers. Verification calculation. Heat transfer in devices for processing plastics, for the production of building materials. <i>General purpose heat exchangers. Basic schemes of heat exchangers. Design and verification calculations of devices.</i> <i>References: [1]</i> <i>Tasks on the SRS. To work out the basic schemes of heat exchangers</i>	2
13	Drying materials. <i>Purpose of the process and its role. Drying units. Characteristics of air as the main drying agent (humidity, relative humidity, moisture content, enthalpy). Statics of the main drying process. Material and thermal balance.</i> <i>References: [1]</i> <i>Tasks on the SRS. To work out the basic schemes of dryer designs</i>	2
14	Theoretical dryer. Air drying with recirculation. The kinetics of the drying process are "drying curve". <i>Theoretical dryer. Actual drying process and its analysis. Diagram of drying processes, construction and calculations of the main drying process using a diagram. Variants of the main drying process and their analysis, ways to intensify and optimize the process. Air drying by recirculating it. Basic analytical relations. Construction and calculations of the process in the diagram. The kinetics of the drying process are "drying curve".</i> <i>References: [1]</i> <i>Tasks on the SRS. Work out the construction of the drying process in the i-d diagram</i>	2
15-17	Non-stationary heat transfer. <i>Heating an infinite plate. Analysis of the resulting solution. The amount of heat given off by the plate. Cooling of the "infinite" cylinder. Equation. Boundary conditions of the third kind. Solution analysis. The amount of heat that the cylinder gives off during cooling. Regular cooling mode. Kondratiev's theorems. Approximate methods for calculating thermal conductivity problems.</i> <i>Cooling (heating) of plates. Cooling of a cylinder, sphere, bodies of finite dimensions. Approximate methods for solving problems of non-stationary heat transfer. References: [1] p. 74-120.</i> <i>Tasks on the SRS. To work out approximate methods for solving problems of non-stationary heat transfer.</i>	6
18	Passed	2

Practical classes

*In the system of professional training of bachelors in this **educational component** , practical classes occupy 25% of the classroom load. Being an addition to the lecture course, they lay and form the foundations of the bachelor's qualification in the field of mechanical engineering, namely the calculation of thermal processes in industry equipment. use special terminology that allows you to test knowledge, so this type of work is an important means of prompt feedback. Practical classes should perform not only cognitive and educational functions, but also contribute to the growth of students as professional workers in the field of applied mechanics.*

The main tasks of the cycle of practical classes:

- *to help students systematize, consolidate and deepen theoretical knowledge in the field of modern methods for calculating heat exchange processes in equipment;*
- *to teach students techniques for solving practical problems, to promote the acquisition of skills and abilities in performing calculations, graphic and other tasks;*
- *to teach them to work with reference literature;*
- *to form the ability to learn independently, that is, to master the methods, methods and techniques of self-study, self-development and self-control.*

No. s/p	Title of the topic of the practical lesson and a list of main questions (list of didactic support, references to literature and tasks on the SRS)	Hours
1	Basic physical quantities, determination of values of physical properties of coolants. Bibliography: [3] p. 5. Tasks on the SRS. To work out the definition of physical properties of air, water, transformer oil.	2
2	Thermal conductivity, method of solving problems. References: [3] p. 7-11. Tasks on the SRS. Work out the definition of heat flux, wall temperature for multilayer walls.	2
3	Basic concepts and parameters, methods for solving free convection problems. Calculations of the heat transfer coefficient during free convection in an infinite space using criterion equations. Selection of equations, determining temperature and size. Bibliography: [3] p. 11-13. Tasks on the SRS. To work out the method of solving problems for free convection in a confined space	2
4	Basic concepts and parameters, methods for solving forced convection problems. Calculations of the heat transfer coefficient in the channel using criterion equations. Bibliography: [3] p. 13-19. Tasks on the SRS. To work out the method of solving problems for the transverse flow of the channel	2

5	<i>Basic concepts and parameters, methods for solving radiant heat transfer problems. Calculation of the heat transfer of radiation between a solid and a gas; between solids.</i> <i>References: [3] p. 19-20.</i> <i>Tasks on the SRS. To work out the methodology for solving problems for heat transfer with screens</i>	2
6	<i>Basic concepts and parameters, methods for solving boiling and condensation problems. Calculation of the heat transfer coefficient during steam condensation. Two determining process temperatures. Phase transition criterion. Checkerboard and corridor bundle of pipes. Selecting the wall temperature and checking it.</i> <i>References: [3] p. 20-25.</i> <i>Tasks on the SRS. To work out the method of solving problems for boiling liquid</i>	2
7	<i>Basic concepts and parameters, methods for solving heat transfer problems. Calculations of the average temperature head, heat transfer coefficients and heat transfer.</i> <i>References: [3] p. 25-28.</i> <i>Tasks on the SRS. To work out the method of solving problems for heat transfer through a multilayer wall</i>	2
8	<i>Basic concepts and parameters, methods for solving problems in non-stationary heat transfer. Calculation of cooling devices. Solution of the problem based on the regularities of non-stationary thermal conductivity</i> <i>References: [3] p. 32-34.</i> <i>Tasks on the SRS. To work out the method of solving problems for an unlimited cylinder</i>	2
9	<i>Modular control work</i>	2
	<i>Just</i>	18

Laboratory classes

*In the system of professional training of bachelors in this **educational component** , practical classes occupy 25% of the classroom load. Being an addition to the lecture course, they lay and form the foundations of the bachelor's qualification in the field of mechanical engineering, namely the preparation and conduct of laboratory studies of thermal processes that take place in industry equipment. measuring equipment, performing calculations, their generalization and creative comprehension. They develop constructive thinking and the ability to use special terminology, allow you to check the knowledge gained in lectures, so this type of work is an important means of prompt feedback. Laboratory classes should perform not only cognitive and educational functions, but also contribute to the growth of students as professional workers in the field of industrial engineering.*

The main tasks of the cycle of laboratory classes:

- to help students systematize, consolidate and deepen theoretical knowledge in the field of modern methods of research on the calculation of heat exchange processes in equipment;*
- to teach students the techniques of obtaining an array of data and their processing, to promote the acquisition of skills and abilities in performing calculations and their graphic processing and generalization;*
- to teach students to work with reference literature;*

- to form the ability to learn independently, that is, to master the methods, methods and techniques of self-study, self-development and self-control.

No. s/p	Title of the topic of the laboratory lesson and a list of main questions (list of didactic support, references to literature and tasks for the SRS)	Hours
1	Study of the process of thermal conductivity in a cylindrical wall in a stationary mode. References: [4] Tasks on the SRS. According to experimental data, build a linear temperature field of a cylindrical wall	4
2	Study of heat transfer of a ceramic cylinder under conditions of free convection. References: [4] Tasks on the SRS. Based on experimental data, build a temperature dependence on the location of the thermocouple	4
3	Study of the processes of thermal radiation of black and gray plates. References: [4] Tasks on the SRS. Based on experimental data, to construct the dependence of the surface temperature of the gray plate on the degree of blackness	4
4	Study of drying of porous bodies with air recirculation. References: [4] Tasks on the SRS. Based on experimental data, build a drying curve	4
5	Laboratory report protection	2
	Just	18

6. Independent work of a student

Independent work takes 40% of the time of studying **the educational component**, including preparation for the test. The main task of independent work of students is to master scientific knowledge in areas that are not included in the list of lecture questions through personal search for information, the formation of an active interest in a creative approach in educational work. introduction of the latest technologies for calculating heat exchange equipment, based on its technological purpose and operating parameters. He must master the basic techniques and methods of calculation.

No. s/p	Name of the topic submitted for independent study	Number of IWS hours
Chapter 1. Entry		
1	Topic 1. Basic concepts and objectives of the course. Problems of the science of heat transfer and heat transfer References: [5] p. 34-46	4
Chapter 2. Thermal conductivity		
2	Topic 2. The basic law of thermal conductivity. Differential equation of thermal conductivity. Thermal conductivity through a single-layer flat wall. Explore the analogy between thermal and electrical resistance References: [5] p. 63-78	2
	Topic 3. Thermal conductivity through multilayer flat wall. Thermal conductivity of single-layer and multilayer cylindrical wall, spherical wall.	2

Chapter 3. Convective heat transfer		
3	Topic 4. The theory of similarity as a theory of experiment. The theory of dimensions. Criterion equations. Criterion equations for laminar washing of a vertical isothermal wall References: [5], p.415 - 418 Topic 5. Convective heat transfer. Free convection. Free convection with different types of surface arrangement References: [5], p. 428-429 Topic 6. Forced convection. Current in the canal. Transverse flow around surfaces. Flowing around a single pipe on a "bundle" of pipes. Calculation formulas. Methods of their use. Calculations of heat transfer of the "bundle" of pipes. Insulation. Critical diameter of thermal insulation. Reynolds–Colborne analogy References: [5], p.313-315	10
Chapter 4. Thermal radiation		
	Topic 7. Basic laws of radiation. Radiation intensity. Heat exchange of radiation between solids. Basic calculation formulas and methods of their use. Degree of blackness. Topic 8. Radiant heat transfer in gases. Physics of the process, heat exchange between solid and gas. Basic calculated ratios. Intensification of the radiant heat transfer process. What is solar energy Bibliography: [5], pp. 590-594	4
Chapter 5. Heat transfer when changing the physical state of matter		
6	Topic 9. Heat transfer during steam condensation. Topic 10. Heat transfer during the boiling of a liquid. Boiling in pipes References: [5], pp. 507-516	4
Chapter 6. Heat transfer and heat exchange equipment		
7	Topic 11. Heat transfer. Topic 12. General purpose heat exchangers. Verification calculation. Heat transfer in devices for processing plastics, for the production of building materials. Functions and designs of heat exchangers References: [5], p. 100-112	6
Chapter 7. Heat and mass transfer		
8	Topic 13. Drying materials. Topic 14. Theoretical dryer. Air drying with recirculation. The kinetics of the drying process are "drying curve". The concept of mass transfer References: [5], pp. 615-618	4
Chapter 8. Non-stationary heat transfer		

9	Topic 15. Non-stationary heat transfer. The basic equation of non-stationary thermal conductivity. Cooling (heating) the plate. Analysis of the resulting solution. The amount of heat given off by the plate. Topic 16. Cooling of an "infinite" cylinder. Equations. Boundary conditions of the third kind. Solution analysis. The amount of heat that the cylinder gives off during cooling. Topic 17. Regular cooling mode. Kondratiev's theorems. Approximate methods for calculating thermal conductivity problems. Electrical and mechanical analogy of non-stationary thermal conductivity References: [5], pp. 196-200	2
10	Preparation for the modular test work	4
11	Preparation for the test	6
	Just	48

Policy and control

7. Educational Component Policy

Rules for attending classes and behavior in the classroom

Attendance at 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's conduct, not to be distracted by actions not related to the educational process.

Rules for assigning incentive and penalty points

- Incentive points can be awarded by the teacher only for the performance of creative work in the discipline or additional completion of on-line specialized courses with the receipt of an appropriate certificate:
 - <https://www.coursera.org/learn/thermodynamics-intro>;
 - <https://www.coursera.org/learn/sustainability-fuels-ash-chemistry-deposits-corrosion-additives>

But their amount cannot exceed 10% of the rating scale.
- Penalty points are provided in case of plagiarism or gross violation of the calculated part of the laboratory work (unacceptable values of values, graphical processing of data that violates the idea of the physics of the process).

Deadline and retake policy

In case of debts from the educational component or any force majeure circumstances, students must independently contact the teacher through the available (provided by the teacher) communication channels to solve problematic issues and agree on an algorithm of actions for working out. The student must report the occurrence of force majeure circumstances immediately after their occurrence, without waiting for the consequences in the form of failure or penalty points.

Academic Integrity Policy

Plagiarism and other forms of dishonest work are unacceptable. Plagiarism includes the absence of references when using printed and electronic materials, quotes, opinions of other authors. Hints and cheating are unacceptable when writing tests, conducting classes; passing a test for another student; copying materials protected by the copyright system without the permission of the author of the work. The policy and principles of academic integrity are defined in Section 3 of the Code of Honor of the National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute". Read more: <https://kpi.ua/code>

Academic Conduct and Ethics Policy

Students should be tolerant, respect the opinions of others, formulate objections in the correct form, and 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". Read more: <https://kpi.ua/code>

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

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

Semester	Study time		Distribution of training hours				Control measures		
	Loans	Acad. H.	Lecture	Practical	Lab. Rob.	SRS	MCW	RR	Semester control
6	4	120	36	18	18	48	1	–	Passed

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

The student's rating in the educational component consists of points that he receives for work in practical and laboratory classes, for performing modular control work.

Semester control is a test.

System of rating (weight) points and evaluation criteria

Rating Score System and Evaluation Criteria:

Completing tasks in practical classes.

The weight score for completing 4 tasks in practical classes is 10 points per task.

Criteria for evaluating the implementation of the practical task

Completeness and signs of task completion	Points
The task is completed in full	10
Untimely completion of a task completed correctly	9-8
Incomplete completion of the task	7-6
Failure to complete or poorly completed task	0

Completing tasks in laboratory classes.

The weight score of 4 laboratory works in laboratory classes is 10 points each.

Criteria for evaluating the implementation of the practical task

Completeness and signs of task completion	Points
Laboratory work was completed in full and delivered on time	10
Untimely completion of the task, but correctly and in full	9-8
Incomplete completion of the task	7-6
Failure to complete or poorly completed task	0

Performing a modular control.

The weight score of the MCW performance is 20 points.

Criteria for evaluating the implementation of the MCW

Completeness and signs of task completion	Points
The MCR is completed in full	20
Minor deficiencies in paragraph 1	19-15
Significant deficiencies in paragraph 1	14-10

<i>Incomplete completion of the task</i>	<i>5-9</i>
<i>Poor performance of the task</i>	<i>1-4</i>
<i>Failure to complete the task</i>	<i>0</i>

Conditions for admission to semester control: *a minimum positive score for practical, laboratory work and MCW of at least 60 points.*

Semester control: *credit.*

The weight score of the test work is 50 points for 2 tasks.

Criteria for evaluating the performance of credit work

<i>Completeness and signs of task completion</i>	<i>Points</i>
<i>The work is done in full</i>	<i>50</i>
<i>Minor deficiencies in paragraph 1</i>	<i>45-49</i>
<i>Significant deficiencies in paragraph 1</i>	<i>38-48</i>
<i>Incomplete completion of the task</i>	<i>30-37</i>
<i>Poor performance of the task</i>	<i>0</i>
<i>Failure to complete the task</i>	<i>0</i>

Thus, the rating semester scale from the educational component is:

$$R = 40 + 40 + 20 = 100 \text{ points}$$

According to the results of educational work for the first 7 weeks, the "ideal student" should score 30 points. At the first attestation (8th week), the student receives "enrolled" if his current rating is at least 15 points.

According to the results of educational work for 13 weeks of study, the "ideal student" should score 60 points. At the second attestation (14th week), the student receives "enrolled" if his current rating is at least 30 points.

The maximum amount of points is 100. Obtaining a credit from the educational component "automatically" is provided under the conditions of gaining 60 or more points per semester.

A prerequisite for admission to the test is a rating that is at least 60% of the performance of practical, laboratory work and MCW, i.e. 60 points.

To obtain a credit score, the sum of all rating points *R* received during the semester is converted according to the table:

<i>Score</i>	<i>Score</i>
<i>95...100</i>	<i>Perfectly</i>
<i>85...94</i>	<i>Very good</i>
<i>75...84</i>	<i>well</i>
<i>65...74</i>	<i>Satisfactory</i>
<i>60...64</i>	<i>enough</i>
<i>RD < 60</i>	<i>Disappointing</i>
<i>Not met the conditions of admission</i>	<i>not allowed</i>

9. Additional information on the educational component

Approximate list of questions submitted for semester control

1. Analyze the basic concepts of heat transfer. List the main methods of heat exchange.
2. Describe what a temperature field is, a temperature gradient, give examples.
3. Analyze Fourier's law (hypothesis), differential and integral form of notation.
4. Analyze the derivation of the differential equation of stationary thermal conductivity.
5. Thermal conductivity through a flat wall under stationary conditions: differential equation, boundary conditions, change in temperature in the wall and calculation of specific heat flux.
6. To list and analyze the unambiguity conditions that are set for the unambiguous solution of heat transfer problems. Boundary conditions.
7. Analyze the process of thermal conductivity through a multilayer flat wall under stationary conditions.
8. Analyze the process of thermal conduction through a cylindrical wall under stationary conditions.
9. Analyze the process of thermal conduction through a multilayer cylindrical wall under stationary conditions.
10. Analyze the basics of similarity theory.
11. To compare the main criteria of similarity in the calculation of heat transfer problems.
12. To provide the concept of dimensionless complexes. The main dimensionless complexes and their physical meaning.
13. Characterize the method of dimensions for solving heat transfer problems.
14. To characterize the formulation of the problem of convective heat transfer.
15. Analyze the Newton-Richmann law, heat transfer coefficient.
16. Differential equation of convective heat transfer.
17. The main criterion equations of convective heat transfer.
18. Heat transfer during forced movement of fluid in pipes.
19. Determination of the coefficient of heat transfer during forced movement of the liquid in a straight pipe of round cross-section.
20. The coefficient of heat transfer during the forced movement of the liquid in pipes with a rounded channel and a non-circular cross-section.
21. Heat transfer in a checkerboard bundle of pipes, calculation of the heat transfer coefficient.
22. Heat transfer in the corridor bundle of pipes, calculation of the heat transfer coefficient.
23. Free convection. Heat transfer during the free movement of the liquid along the vertical plate.
24. Free convection. Heat transfer when moving a liquid in a confined space.
25. The concept of radiant heat transfer, the Stefan-Boltzmann law. Heat exchange between solids separated by a transparent medium.
26. Analyze the Stefan-Boltzmann law for completely black and gray bodies..
27. Analyze the types of radiation fluxes. Completely black, white, transparent bodies.
28. Analyze the heat transfer of radiation in the presence of screens.
29. Characterize the concept of the degree of blackness of bodies, the degree of blackness is given.
30. Complex heat transfer, definition, concept, basic calculation equations.
31. Thermal calculation of heat exchangers, types, methods.
32. Classification of heat exchangers, basic designs.
33. Heat transfer equation. Heat transfer coefficient, coolant flow patterns, average temperature pressure.
34. Classification of heat exchangers by design
35. Design calculation of surface type heat exchangers.
36. Verification calculation of surface type heat exchangers.
37. The concept of gas condensation. Heat transfer during condensation of water vapor.
38. Heat transfer during film condensation.
39. Heat transfer during boiling. Two boiling modes.
40. Heat transfer during boiling. Two boiling crises.
41. Boiling, boiling modes, basic concepts.
42. Describe the process of drying materials. Drying agents. Air as a drying agent.
43. To characterize the process of drying materials.. Structure of the I-x diagram of moist air.

44. Describe the process of drying materials. Statics of the main drying process.
45. Describe the process of drying materials. Heat balance of dryers.
46. Describe the process of drying materials. Drying with air recirculation.
47. To characterize the process of drying materials.. Drying kinetics.
48. Non-stationary heat transfer. Differential equations and unambiguity conditions.
49. Analyze the cases when $Bi \rightarrow \infty$ and $Bi \rightarrow 0$ in the problem when the plate is cooled.
50. The method of finding the roots of μ in the problem of cooling the plate.

Approximate list of questions submitted for modular control work

1. Analyze the application of Fourier's law for a flat plate (formulation and equation).
2. Problem. How much heat is lost through a wall made of red brick ($\lambda=0.7$ W/m.K) with a thickness of 500 mm, an area of 1 m^2 , if the wall temperature in the room is 20°C , and outside -20°C (minus 20)?
3. Give what criterion is used to determine the mode of movement of the liquid during forced convection? How is it calculated for round and non-circular channels?
4. Analyze and define the temperature field, explain what an isothermal surface is, give examples.
5. Task. To determine the heat loss from the surface of the heat exchanger, Q , W , into the environment under the following conditions: surface area of the apparatus $F=15 \text{ m}^2$, surface temperature 80°C , average air temperature 25°C , heat transfer coefficient $\alpha = 5 \text{ W/m}^2 \cdot \text{K}$.
6. Explain by what criterion the lifting force arising in a liquid due to the difference in density is characterized.
7. Analyze the concept of temperature gradient.
8. Task. Determine the linear heat flux through a cylindrical wall (pipe) made of steel ($\lambda=20$ W/m.K), if its inner diameter is 20 mm, outer diameter 25 mm, the temperature of the outer surfaces of the pipe walls $t_{c1}=80^\circ\text{C}$, $t_{c2}=50^\circ\text{C}$.
9. What are the names of dimensionless complexes that consist of heterogeneous physical quantities, give examples.
10. How the Grashoff criterion is determined, give a formula explaining the quantities included and the physical meaning, analyze the dimensions.
11. Problem. How much heat is lost through a red brick wall ($\lambda_1=0.7$ W/m.K) 500 mm thick, covered with a layer of insulation, 20 mm thick ($\lambda_2=0.25$ W/m.K) from an area of 1 m^2 , if the wall temperature in the room is 20°C , and outside -20°C (minus 20)?
12. What size is decisive in the calculation of heat transfer during the transverse flow of a horizontal bundle of pipes? How is the heat transfer coefficient calculated in this case?
13. How the Nusselt criterion is determined (formula and physical sense).
14. Problem. Determine the mode of air movement in pipes with a diameter of $d = 60 \text{ mm}$ at a speed of $w= 6 \text{ m/s}$, if the kinematic viscosity of air is $\nu = 24 \cdot 10^{-6} \text{ m}^2/\text{s}$?
15. Analyze the differential equation of stationary thermal conductivity (without internal heat sources) and the unambiguity conditions that must be set to solve it.
16. Analyze what physical meaning the Reynolds criterion has, write down the formula and the physical quantities involved.
17. Task. Determine the heat loss by the heat exchanger, Q , W , to the environment under the following conditions: the surface of the apparatus $F=15 \text{ m}^2$, the surface temperature is 80°C , the average air temperature is 25°C , the heat transfer coefficient $\alpha = 5 \text{ W/m}^2 \cdot \text{K}$.

18. How is it taken into account in the calculations of forced convection that the flow of the coolant occurs in a channel of non-circular cross-section (rectangle, square, ring)?
19. Analyze the Newton-Richmann law and its application in engineering calculations.
20. Task. Determine the thermal conductivity coefficient λ of a flat plate if its thickness $\delta = 0.04$ m, the temperature difference between the surfaces is $\Delta t = 40$ K, and the density of the heat flux passing through the plate is $q = 80,000$ W/m².
21. Determine the diameter equivalent to the square channel with side a .
22. Analyze Fourier's Law (Formulation and Differential Form)
23. Problem. How much heat is lost through a wall with a thickness of 500 mm, made of red brick ($\lambda = 0.7$ W/m.K) from an area of 1 m^2 , if the wall temperature in the room is 25°C , and outside -15°C (minus 15) ?
24. Determine the diameter equivalent to the channel of rectangular section with sides $c \times c$.
25. What is a temperature field (definition), which surface is called isothermal.
26. Task. To determine the heat loss from the surface of the heat exchanger Q , W , into the environment under the following conditions: surface area of the apparatus $F = 12 \text{ m}^2$, surface temperature 80°C , average air temperature 25°C , heat transfer coefficient $\alpha = 6 \text{ W/m}^2 \cdot \text{K}$?
27. Determine the diameter equivalent to an annular channel with dimensions d_1 and d_2 .
28. Analyze the concept of temperature gradient.
29. Problem. Determine the linear heat flux through a cylindrical steel wall ($\lambda = 25$ W/m.K), if the inner diameter is 20 mm, the outer diameter is 25 mm, the temperature of the pipe walls $t_{c1} = 80^\circ\text{C}$, $t_{c2} = 50^\circ\text{C}$.
30. Analyze the geometric characteristics of a checkerboard bundle of pipes in the calculations of heat exchangers.
31. Grassgoff criterion (formula and physical sense).
32. Problem. How much heat does a wall 500 mm thick, made of red brick ($\lambda_1 = 0.7$ W/m.K), covered with a layer of insulation, 20 mm thick ($\lambda_2 = 0.25$ W/m.K) lose from an area of 1 m^2 , if the wall temperature in the room is 25°C , and outside -15°C (minus 15) ?
33. Geometric characteristics of the corridor bundle of pipes in the calculations of heat exchange equipment.
34. Nusselt criterion (formula and physical sense).
35. Problem. Determine the mode of air movement in pipes with a diameter of $d = 60$ mm at a speed $w = 1$ m/s, if the kinematic viscosity' of air is $\nu = 24 \cdot 10^{-6} \text{ m}^2/\text{s}$?
36. How to calculate the average heat transfer coefficient for a bundle of pipes from n rows.
37. Reynolds criterion (formula and physical sense).
38. Task. Determine the heat loss by the heat exchanger, Q to the environment under the following conditions: the surface of the apparatus $F = 15 \text{ m}^2$, the surface temperature is 75°C , the average air temperature is 20°C , the heat transfer coefficient is $\alpha = 5 \text{ W/m}^2 \cdot \text{K}$?
39. What correction is introduced when calculating the forced heat transfer in a curved pipe with a bending radius R ?
40. Application of the Newton-Richmann law in heat transfer problems.
41. Task. Determine the thermal conductivity coefficient λ of a flat plate if its thickness $\delta = 0.05$ m, the temperature difference between the surfaces is 50 K, and the density of the heat flux passing through the plate $q = 80,000$ W/m².
42. What is the criterion for determining the mode of fluid movement during forced convection?
43. Fourier's law (diff. equations and formulations).

44. Task. Calculate the Grashof criterion for air that washes a horizontal pipe with a diameter of $d = 100$ mm, with a surface temperature of 400°C . Air parameters: temperature 20°C , kinematic viscosity $15.00 \cdot 10^{-6} \text{ m}^2/\text{s}$.
45. Formulation and application of the Stefan-Boltzmann law in heat transfer problems.

Work program of the educational component (syllabus):

Compiled by Assoc. Prof., Ph.D., Shilovych T.B.

Approved by the Department of ____ CPSM ____ (Minutes No. 17 dated 04.06.2025)

Approved by the ICF Methodological Commission (Minutes No. 11 dated 27.06.2025).)