Національний технічний університет України
«КИЇВСЬКИЙ ПОЛІТЕХНІЧНИЙ ІНСТИТУТ
імені ІГОРЯ СІКОРСЬКОГО»

Department of machines and devices of chemical and oil refining industries

NAME OF THE COURSE

Modeling the state of a continuous environment

Working program of the academic discipline (Syllabus)

Details of the academic discipline

Level of higher education	**The third (educational and scientific)**
Branch of knowledge	13 Mechanical engineering
Specialty	133 Industrial engineering
Educational program	ONP Industrial Engineering
Discipline status	Normative
Form of education	full-time (daytime)/full-time (evening)/correspondence/distance/mixed
Year of training, semester	2nd year, autumn semester
Scope of the discipline	4 (120)
Semester control/ control measures	Exam
Lessons schedule	3 hours per week (1 hour of lectures and 2 hours of practical classes)
Language of teaching	Ukrainian
Information about head of the course / teachers	Lecturer: Ivanytskyi Georgy Kostiantynovych, doctor of technical sciences, professor. Practical/Seminar: Georgy Ivanytskyi, gergey4@gmail.com
Placement of the course	Link to remote resource (Moodle, Google classroom, etc.)

Program of study discipline

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

Description of the academic discipline.

Mathematical modeling methods are widely used in the study of various systems and processes - natural, technical, environmental, etc. This involves the creation of a conceptual model of the research object, its formalization and transformation into a mathematical model in an analytical or numerical form suitable for obtaining the final solution to the problem. Implementation of numerical analysis algorithms is usually carried out on the basis of modern computer technologies using specialized software packages. But for this, the researcher needs to have the basics of mathematical modeling, the ability to develop adequate mathematical models, to carry out their modification, since the use of specialized packages always implies the need to choose the optimal algorithm and ways of its successful implementation, sometimes from many possible options.

The course focuses attention on the close relationship between full-scale modeling of objects and processes with the conduct of experimental studies on laboratory stands and mathematical modeling of these processes, which, on the one hand, provides the possibility of checking the adequacy and reliability of the model, ways of its further modification, and on the other - conducting a detailed analysis of the results of the experiment and substantiating the ways of further direction of laboratory research, making the necessary changes in the methodology of conducting experiments

The subject of the academic discipline.

The discipline "Modeling the state of a continuous environment" is taught as a new universal component of training qualified specialists in the field of mechanical engineering, resource conservation, ecology and computer-integrated technologies. The course covers generalized methods of modeling hydrodynamic, heat exchange and mass exchange processes, as well as methods of creating models that are basic for studying these processes. The models are considered, which are built from the single positions of the laws of conservation of mass, momentum, and energy, and the influence of specific and general mechanisms of interaction between objects and the environment on these models.

Mastering the methods of mathematical modeling involves not only mastering certain rules and methods of action in model building algorithms and choosing a solution method, but rather the development of a peculiar style of thinking, focused on the analysis of the physical and mathematical essence of the considered phenomena. The mastering of modern technologies in the field of "Industrial Mechanical Engineering" increasingly requires deep and systematic multidisciplinary training from a graduate student, a mechanical engineer, and the involvement of knowledge and experience accumulated in other disciplines of physical-mathematical and chemical-technological directions.

The purpose of the educational discipline.

The goal of mastering this discipline is the formation of complex knowledge, skills and abilities that allow using the fundamental principles of mechanics and thermodynamics to model a wide class of physical and mechanical processes in solid environments. In addition, as a result of mastering the discipline, graduate students will familiarize themselves with the methodology of scientific research using modern program-target complexes of physical and mathematical modeling, master the ability to use basic scientific knowledge and methods to form judgments on professional problems when solving complex scientific and technical tasks, critically evaluate and interpret research results, draw conclusions obtained in complex and uncertain situations.

The set goals will allow graduate students to gain a deeper understanding of mathematical modeling methods, to understand the nature of the considered heat and mass transfer and hydrodynamic phenomena and processes that are the subject of scientific research, to develop technological skills in building appropriate mathematical models. The study of course problems will be focused on the active use of domestic and foreign publications in the field physical and mathematical modeling of the state of the continuous environment.

In accordance with the purpose of this educational discipline, the preparation of doctors of philosophy in the specialty 133 Industrial mechanical engineering requires further development of the competencies developed by graduate students:

In accordance with the purpose of this educational discipline, the preparation of doctors of philosophy in the specialty 133 Industrial mechanical engineering requires further development of the competencies developed by graduate students:

- to know the fundamentals of the theory of hydrodynamics, heat and mass transfer, and the basic principles of thermodynamics;

- to be able to formulate a scientific problem in the field of mechanical engineering, justify working hypotheses for solving the investigated problem;

- to know the main classes of mathematical models of continuous environments, the general methods of their construction based on the physical laws of conservation, the corresponding balance equations;

- to have the skills to apply mathematical models of continuous environments for modeling various physical and mechanical processes, to make the correct choice of model and to adapt it for modeling the behavior of the research object.

According to the requirements of the program of the study discipline "Modeling of the state of a continuous environment", post-graduate students, after learning the materials of the lecture course, must demonstrate the following pprogram learning outcomes:

- be able to develop and research conceptual mathematical and computer models of processes taking into account the properties of the continuous environment, carry out their mathematical solution, analyze the results,

- to know the modern methods of formalization of the states of a continuous environment, the main types of determining ratios characterizing the behavior and reaction of research objects within the framework of generalized models of continuous environments;

- be able to improve models of the state of continuous environments, apply the acquired skills and studied material to solve new problems of the dynamics of continuous environments;

- be able to analyze the state of the continuous environment and substantiate working hypotheses regarding the improvement of the efficiency of transfer processes;

- be able to effectively apply methods of analysis, mathematical modeling, perform physical and computational experiments in the process of conducting scientific research, solve complex problems in the field of mechanical engineering, conduct research and innovation activities that involve a deep understanding of existing and the creation of new integral knowledge, as well as practical implementation obtained results;

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

Mastering the discipline"Modeling of the state of a continuous environment" is based on the principles of integration of the complex of knowledge obtained by graduate students during bachelor's education and master's degree when studying natural and engineering-technical disciplines in the field of "Mechanical Engineering".To successfully master this discipline, it is necessary to have basic knowledge in the field of higher mathematics, physics, physical chemistry, theoretical foundations of heat engineering, general chemical technology; know the basic principles of the theory of heat and mass transfer, hydromechanical and mechanical processes: be able to use a computer at the level of an administrator; have skills in applied programming, mathematical modeling of processes and systems.

As a result of mastering the discipline, the graduate student will know the methodology of scientific research using modern program-target complexes of physical and mathematical modeling, will be ready to use fundamental and natural scientific knowledge and methods to form reasoned judgments when solving complex scientific and technical problems in the field of professional and research and innovation activities that involve deep rethinking of existing and creation of new integral knowledge and fruitful professional practice.

3. Content of the academic discipline

Chapter 1 Basics of physical and mathematical modeling.

Topic 1.*Natural and mathematical modeling. Objects of research. Methods of mathematical modeling.*

Topic 2*. Basic requirements for the mathematical model.*

Chapter 2. Classification of mathematical models.

Topic 3.*Classification of models depending on the complexity of the modeling object, parameters and operator*

Topic 4.*Classification of mathematical models depending on the purpose of modeling and implementation methods.*

Section 3.*Application of mathematical modeling methods in conducting scientific research.*

Topic 5.*Stages of building physical and mathematical models. Determining factors of building a mathematical model.*

Topic 6.*Setting up research and solving computational problems. Formalization of the mathematical model.*

Topic 7.*Modeling the movement of dispersions in a continuous medium.*

Section 4.*Mathematical models of continuous environment*

Topic 8.*Definition of the concept of continuous environment. Basic equations of the mathematical model.*

***Topic 9**. Mathematical modeling based on the fundamental laws of nature. Classification of transport mechanisms.*

Chapter 5. Methods of deriving the basic equations of the continuous medium model

***Topic 10**. The differential equation of inseparability.*

***Topic 11.**Differential equation of fluid motion or momentum equation. Derivation of the Navier-Stokes equation.*

***Topic 12.**Differential equation of conservation of energy. Derivation of the heat conduction equation.*

***Topic 13**Procedure for solving differential equations.*

4. Educational materials and resources

Basic literature

1. Grinchenko V.T., Mechanics of liquid, gas and plasma. //Encyclopedia of Modern Ukraine: electronic version [website] /Hol. editor: I.M. Dzyuba, A.I. Zhukovsky, M.H. Zheleznyak et al. – Kyiv: Institute of Encyclopedic Research of the NAS of Ukraine, 2018. URL:http://esu.com.ua/search_articles.php?id=67464

2. Vanin V. A. Mathematical models and numerical methods in the problems of the mechanics of a solid medium: teaching method. manual for the course "Modern problems of mathematical and computer modeling" for students. engineering and energy specialists. / V. A. Vanin; National technical University "Kharkiv Polytechnic Institute". – Kharkiv: NTU "KhPI", 2018. – 209 p.

3. Bilushchak Y., Haivas B., Hera B. and others. Mathematical modeling of non-equilibrium processes in complex systems. Under the editorship E. Chapli. - Mathematical Modeling Center of the Institute of Applied Problems of Mechanics and Mathematics named after Ya. S. Pidstrychacha of the National Academy of Sciences of Ukraine. Lviv: Rastr – 7, 2019.–256 p.

4. Semenova I.Yu. Mathematical models of the mechanics of continuous media Study guide Kyiv: Taras Shevchenko Kyiv National University 2014. –82p. http://www.mechmat.univ.kiev.ua/wp-content/uploads/2018/03/MatModelMSSlast.pdf

5.LaiwmRubinR.,Kremp E.L.Introduction to Continuum Mechanics,Elsevier Science, 2009, 881

Additional

6. Sakharov O.S., Karvatskyi A.Ya. Mechanics of continuous media in engineering calculations: For students of the specialties "Equipment of chemical production and construction materials enterprises".- Kyiv: NTUU "KPI", 2013.-231 p. https://cpsm.kpi.ua/Doc/MSS-1.pdf

7. Andersen DA, Tannehill JS, Pletcher RH Computational fluid mechanics and heat transfer. N.Y.: Hemisphere Publishing Corporation, 1984, 380

*8.**Chadwick P. Continuum Mechanics: Concise Theory and Problems, Dover Publication, 2012, 200***

9. Husainov D.Ya., Kharchenko I.I., Shatyrko A.V. Introduction to modeling of dynamic systems: Training. manual. Kyiv: Kyiv National University named after Taras Shevchenko, 2010.–130 p.

10. Bechtel SE, Lower RL Fundamental of continuous mechanics with application to mechanical, thermo mechanical and smart materials Academic Press 2014, 330

11. Pavlenko P.M. Fundamentals of mathematical modeling of systems and processes: Teaching. guide.–Kyiv: Knyzh. edition of NAU, 2013.–201 p. https://cpsm.kpi.ua/Doc/MSS-1.pdf

12. Bekas B.O., Kapran I.D., Shimanskyi V.M. Matlab in numerical methods. Using a mathematical package for solving applied problems". Kind. NLTUU. Lviv. 2016. -170.

13. Jörgen BergströmMechanics of Solid Polymers, William Andrew Publication, 2015, 590

14.ZeidanB.AMathematical Modeling of Environment Problems" 2015 In book: Environmental Sci. & Engng., Vol. 7: Instrumentation Modeling and Analysis, Studium Press LLC, USA, 2015, 423-461

5. Methods of mastering an educational discipline (educational component)

Lecture classes.

Lecture classes are aimed atprovision of modern holistic knowledge in the discipline "Modeling of the state of a continuous environment", definition at the modern level of the development of science in the field of modeling when conducting comprehensive research; presentation of new scientifically based methods of mathematical modeling, development of computer programs in accordance with each specific task and ways of their implementation; description of concepts, basic principles of construction and application of mathematical models in scientific research and in engineering practice; ensuring fruitful work of graduate students during the lecture; application of effective methods of teaching, presentation of material and its assimilation; education of postgraduate students' professional qualities and development of creative thinking; formation of their scientific and practical interest in mastering the course material, the desire for independent work.

No s/p	***Name of the topic of the lecture, list of main questions, references to the literature and tasks on the SRS.***	***Hour***
1	***Natural and mathematical modeling. Research objects.*** *Definition of a mathematical model. Physical model. Properties of models. Purpose of modeling. Conceptual modeling.Intuitive modeling.* *Literature: [2], [6] p.13-20, [9] p.6-9, [10] p.7-16, [14] p.6-21, [11] p.38-49 , [8] pp. 11-21. [7] pp. 10-22.*	***1***
2	***Basic requirements for the mathematical model.*** *Multiplicity and unity of models. Completeness and simplicity of the model. Adequacy of the model. Scope and reliability limits. Availability of communication and model management. Modification of the model.* *Literature: [1], [9] p.10-12, [10] 7-16, [11] p.49-60, p.71-74, [12].*	***1***
3	***Classification of models depending on the complexity of the modeling object, parameters and operator.*** *Types of mathematical models and methodology. Structural and functional models. Discrete and continuous models. Linear and non-linear models. Linearization. Linear equations and the principle of superposition. The concept of "simple model" from the point of view of its formalization. Deterministic and stochastic modeling. Dimensionality of the model.* *Literature: [4], [8] p.11-25, [9] p.12-17, [10] p.17-34, : [4] p. 237-242, [13] pp. 6-11, [12] pp. 36-56, pp. 245-260.*	***1***
4	***Classification of mathematical models depending on the purpose of modeling and implementation methods.*** *Features of the model, one of the parameters of which is time. Dynamic and static models. Descriptive and optimization models. Multi-criteria optimization problems. The concept of a structural model. Submodels (sub-models).* *Literature: [2], [8] p.202-270, [11] p.67-71, [12] p.36-56, p. 142-180.*	***1***
5	***Stages of building physical and mathematical models.*** *Determining factors of building a mathematical model. Methods of mathematical modeling. Methods of model implementation. Analytical methods. Numerical Methods. Graphic methods Use of information technologies. Standard models.* *Literature: [10] p.35-45, p..78-92, [14] p.225-235, [11] p. 94-102, 154-162, [12] pp. 56-86.*	***1***
6	***Setting up research and solving computational problems.*** *Formulation of the problem of mathematical modeling. Formalization of the mathematical model. Computational experiment. Adequacy check. Analysis of simulation results. Physical paradoxes in modeling. The reasons for their occurrence.* *Literature: [1-3], [10] p.104-140, [13] p.12-36, [11] p.38-42, p.88-112, [12] p.245-260.*	***1***

7	***Modeling the movement of dispersions in a continuous medium.*** *Influence of mass forces and flow acceleration on the relative speed of movement of dispersions. Influence of the density of the dispersed and solid phase. . The equation of motion of dispersed particles in a continuous medium. The main areas of application of the mathematical model.* *Literature: [14] p. 149-162, [13] p. 176-181, pp. 213-215, 224-226.*	***1***
8	***Definition of the concept of continuous environment.*** *The concept of continuum. Problems of studying the state of continuous environments. Methods of modeling the state of continuous environments. The main hypotheses of the mechanics of continuous media. The basic equations of the mechanics of continuous media. Equation of state. The equation of inseparability. The equation for the transfer of momentum, energy and mass. Physical justification of equations.* *Literature: [2] p.10-26, p.102-116 [6] p.20, p.60-66, [9] p.25-30, [13] p. 38-59.*	***1***
9	***Mathematical modeling based on the fundamental laws of nature.*** *Classification of transport mechanisms. Fick's law and diffusion. Fourier's law and heat conduction. Newton's law and viscous friction.* *Derivation of local balance equations from integral conservation laws. Write the balance equations in the Euler and Lagrange representation.* *Literature: [1] p.11-15, 58-82, [2] 66-86, [3] p. 17-55, [6] pp. 199-230.*	***1***
10	***Differential equation of inseparability.*** *Conservation of mass of matter. with. 58-65. Differential operator. The gradient of a scalar function. Flow of magnitude. Divergence of a vector field. Vector field rotor. Full derivative. Partial derivative. Substantial derivative. The continuity equation for compressible and incompressible fluids.* *Literature: [6] p. 66-70, [8] p. 58-65, [9] pp. 55-60, [13] pp. 38-62, [4] pp. 48-50.*	***1***
11	***Differential equation of fluid motion or momentum equation.*** *Law of conservation of momentum. Navier-Stokes equation. Transfer of the amount of movement in the elementary zone, in the elementary cell. Forms of recording the differential equation of motion. Equations of motion in the Cartesian, cylindrical, spherical coordinate system.* *Literature: [1], [3] p. 52-64, [7] p. 585-630. [8] p. 93-95, [6] p.94-110, [9] p.17-30, [14] p.148-176,*	***1***
12	***Differential equation of energy conservation.*** *Law of conservation of energy. Laplace's equation. Derivation of the heat conduction equation. Movement of solid, liquid and gaseous bodies with phase transformations. Basic and standard equations of heat conduction in the Cartesian, cylindrical and spherical coordinate systems.* *Literature: [8] p. 66-76, [9] p.25, [14] p.225-365, [13] p. 138-180, [3] p. 110-1680*	***1***
13	***Procedure for solving differential equations.*** *Unambiguity conditions. Initial and boundary conditions.Computer implementation of mathematical models of systems.Information systems and computer programs for modeling technical systems. Modern packages of application programs* *Literature: [2,5], [8] p.70-78, [10] p. 164-174, [11] pp. 130-142, [10].*	***1***
Hours in general		***13***

Practical training.

When studying a credit module, 2/3 of the classroom load is allocated to practical classes. A practical lesson on a separate topic of this discipline is aimed at consolidating the material presented in *the lecture by considering specific examples, exercises and problems on this topic. This gives graduate students the opportunity to systematize and deepen theoretical knowledge regarding modern methods of developing a mathematical model, checking its reliability and adequacy, methods of modifying the model if it is necessary to improve or simplify it. At the same time, attention is focused on the close relationship between the methods of full-scale modeling on laboratory stands and mathematical modeling when conducting complex scientific research. In practical classes, when solving applied problems, graduate students master the skills of compiling a system of differential equations of a model with boundary conditions and solving them by analytical methods or numerical methods using modern application software packages. The practical session is conducted in a dialogue mode with educational discussions. In the course of the lesson, a control survey of the students is conducted based on the materials of the previous lectures, their familiarization with literary sources on the subject of the discipline.*

No s/p	**Name of the subject of the practical session, list of main questions, references to the literature.**	**Hour**
1	***Physical and mathematical modeling. Object of study. Mathematical formulation of the modeling problem*** *Definition of the research object. Definition of a mathematical model. Purpose of modeling. Basic assumptions. Properties of models.* *Literature: [6] p.13-20, [10] p.7-16, [11] p.38-49, [12] p.11-21.*	**2**
2	***Ability to create physical models and mathematical models. Model requirements.*** *Completeness and simplicity of the model. Adequacy of the model. Scope and reliability limits. Availability of communication and model management. Modification of the model.* *Literature: [9] p.10-12, [10] 7-16, [2] p.49-60, p.71-74, [12].*	**2**
3	***Types of mathematical models and methodology***. *Examples of deterministic and stochastic models. Dimensionality of the model. The method of similarity and dimensionality analysis when building a physical and mathematical model.* *Literature: [1] p.11-25, [8] p.36-56, p.245-260.*	**2**
4	***Implementation of a mathematical model in the form of a computer program.*** *Dynamic and static models. Descriptive and optimization models. Methods of implementing the model. Analytical and numerical methods. Graphic methods Concept of structural model. Submodels.* *Literature: [5], [8] p.202-270, [11] p.67-71, [12] p.36-56, p. 142-180.*	**2**
5	***Conceptual and mathematical formulation of the modeling problem***. *Determining factors of building a mathematical model. Methods of mathematical modeling. Use of information technologies. Standard models.* *Literature: [3,4], [10] p.35-45, p..78-92, [14] p.225-235, [11] p. 94-102, 154-162, [12] pp. 56-86.*	**2**
6	***Setting up research and solving computational problems.*** *Formulation of the problem of mathematical modeling. Formalization of the mathematical model. Computational experiment. Adequacy check. Analysis of simulation results. Physical paradoxes in modeling.* *Literature: [3], [50], [10] p.104-140, [13] p.12-36, [11] p.38-42, p.88-112, [12] p.245- 260.*	**2**
7	***Modeling the movement of dispersions in a continuous medium.*** *Derivation of the general equation of motion of dispersed particles in a continuous medium. The main areas of application of the mathematical model.*	**2**

	Movement of gas, liquid, solid dispersions in the gravitational field, in centrifuges. Soaring speed. *Literature [3] p. 176-181, p. 213-226 [11] p. 94, [14] p. 149-162,.*	
8	***Methods of modeling the state of continuous environments.*** *Basic equations of solid medium mechanics. Physical justification of equations. Equation of state. The equation of inseparability. The equation for the transfer of momentum, energy and mass.* *Literature: [2], [4], [6] p.20, p.60-66, [9] p.25-30, [13] p. 38-59.*	***2***
9	***Mathematical modeling based on the fundamental laws of nature.*** *Classification of transport mechanisms. Fick's law and diffusion. Fourier's law and heat conduction. Newton's law and viscous friction.* *Derivation of local balance equations from integral conservation laws. Write the balance equations in the Euler and Lagrange representation.* *Literature: [6] 66-86, [8] pp. 11-15, 58-82, [9] pp. 17-55, [13] pp. 199-230.*	***2***
10	***Differential equation of inseparability.*** *Conservation of mass of matter. Differential operator. The gradient of a scalar function. Full derivative. Partial derivative. Substantial derivative. The continuity equation for compressible and incompressible fluids.* *Literature: [6] p. 66-70, [7], [8] p. 58-65, [9] pp. 55-60, [13] pp. 38-62,*	***2***
11	***Differential equation of fluid motion or momentum equation*** *Law of conservation of momentum. Navier-Stokes equation. Transfer of the amount of movement in the elementary zone, in the elementary cell. Forms of recording the differential equation of motion. Equations of motion in the Cartesian, cylindrical, spherical coordinate system.* *Literature: [8] p. 93-95, [6] p.94-110, [9] p.17-30, [14] p.148-176, [10] p. 52-64, [7] p. 52-64,*	***2***
12	***Differential equation of energy conservation.*** *Law of conservation of energy. Laplace's equation. Derivation of the heat conduction equation. Basic and standard equations of heat conduction in the Cartesian, cylindrical and spherical coordinate systems. Motion of solid, liquid and gaseous bodies with phase transformations. Heat conduction equation for a stationary solid body. The equation of heat transfer in an incompressible fluid flow. The equation of heat transfer in a flow taking into account viscous dissipation.* *Literature: [8] p. 66-76, [9] p.25, [14] p.225-365, [13] p. 138-180, [7] p. 260-310*	***2***
13	***Procedure for solving differential equations.*** *Unambiguity conditions. Initial and boundary conditions.Computer implementation of mathematical models of systems.Information systems and computer programs for modeling technical systems. Modern packages of application programs* *Literature: [5], [7], [8] p.70-78, [10] p. 164-174, [11] pp. 130-142,.*	***2***
	Hours in general	***26***

6. Independent work of a student/graduate student

When teaching the educational discipline "Modeling the state of a continuous environment", the independent work of a graduate student takes up 75% of the time of studying the credit module, taking into account the preparation for the exam. Independent work of graduate students includes preparation for classroom classes, completion of two individual assignments in the form of essays, and study of sections of the program and topics that are not included in the list of lecture questions or require more detailed study. The acquisition of knowledge on these topics is carried out through detailed *familiarization with the relevant sections of the recommended basic and additional literature and independent scientific and informational research on one's own initiative. Preparation of a graduate student for the next classroom classes involves mastering the material of the previous lectures in the process of independent work.*

No s/p	**Type of work and titles of topics submitted for independent study**	**Number of hours**
1	**Preparation for classroom classes.**	**40**
2	**Performance of individual practical tasks on the topic of the module.**	**12**
	Working out sections of the program and topics that are not taught in lectures.	
3	**Chapter 1 Basics of physical and mathematical modeling.** *Basic concepts of mathematical modeling.* *Literature [3], [8] p.11-25, [7] Part 1, [12], [14] p.7-38,*	**3**
4	**Chapter 2. Classification of mathematical models.** *Linear and non-linear models. Linear equations and the principle of superposition.* *Literature [4], [12] pp. 245-310,*	**6**
5	**Chapter 3. Application of mathematical modeling methods in conducting scientific research.** *Construction of a mathematical model and computational experiment.* *Examples of mathematical models in physics, chemistry, biology* *Literature [1], [7], [8], [14] pp. 38-81.*	**4**
6	**Section 4.** *Mathematical models of continuous environment* *Laws of conservation in the physics of continuous media. Equations of motion, variational principles and conservation laws. Write the balance equations in the Euler and Lagrange representation.* *Literature [8] p.93-105, [6] p. 20-30, p. 66-71, [7] T.1, p. 279-300*	**4**
7	**Chapter 5. Methods of deriving the basic equations of the continuous medium model** *Modeling of hydromechanical processes* *Literature [14] pp. 148-176* *Modeling of heat exchange processes* *Literature [14] p. 178-220* *Modeling of mass exchange processes* *Literature[14] p. 225-365*	**6**
8	**Numerical methods for solving equations of fluid mechanics and heat transfer.** *Application of the finite difference method for solving model equations.* *Literature [7] Part 1.* *Modern packages of application programs* *Literature [11] pp. 130-150. [10].*	**6**
9	**Preparation for the exam**	
	Hours in general	**81**

Policy and control

7. *Policy of academic discipline (educational component)*

Rules for attending lectures and practical classes;

Attending lectures and practical classes is a mandatory component of studying the material. At the lecture, the teacher uses his own presentation material. Graduate 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 be distracted by activities unrelated to the educational process.*

The graduate student presents the individual practical task completed within the specified time in the form of an abstract with a presentation in the form of a short report.

Policy of deadlines, rescheduling and incentive rules;

Missed classes must be made up. The graduate student independently prepares a synopsis of the missed lecture or practical session, answers control questions to the teacher on the materials of the topic of the missed session. Individual practical tasks should be performed carefully and in a precisely defined time. Fulfillment of these requirements ensures an increase in the rating assessment of the results of mastering the educational discipline.

Academic Integrity Policy;

The policy of the academic discipline is built taking into account the norms of the legislation of Ukraine regarding academic integrity, the Code of Honor of NTTU "Ihor Sikorskyi Kyiv Polytechnic Institute" and is determined by the system of requirements that the teacher presents to the student when studying the discipline (rules of behavior in classes, absences, retakes, etc.) .

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

Distribution of study time by types of classes and tasks in the discipline according to the working study plan:

Training time		Distribution of study hours				Control measures		
Credits	Acad. hours	Lectures	Practical	Lab. do	SRS	MKR	RR	Semester control
4	120	13	26	–	81	-	–	exam

Control of the knowledge of graduate students is carried out with the help of an interview during practical classes, the results of individual practical tasks, and at the exam - with the help of tickets.

During the evaluation, the following is taken into account:

1. Attending lectures and practical classes, productive work during classroom classes.
2. Timely and accurate performance of control practical tasks for independent work.
3. Study of basic and auxiliary literature.

1. The rating of the graduate student from the credit module consists of the points he receives for working in classroom classes (13 hours of lectures and 26 hours of practical classes), for completing two individual practical tasks on the topic of the module, and for the results of the semester control - exam.

2. Scoring criteria:

2.1. Work in classroom classes:
- fruitful work - 1 point;
- passive work or absence from class –0 points.

The maximum number of points for work during classroom classes is 39.

2.2. Criteria for evaluating the performance of one individual practical task

Completeness and timeliness of task performance	***Points***
Full execution, proper design of work, submission on time	***8***
The work was completed in a timely manner, but there are certain shortcomings in the performance of the work	*6*
The work was completed on time, but with significant shortcomings	*2-3*
The work is submitted later than the specified deadline	*4*
The work was completed late with certain shortcomings	*3*
The work was completed late with significant	*1*

deficiencies	
The work is not done	*0*

The maximum number of points for perfect performance of both practical tasks is 16.

For 13 weeks of study, based on the results of academic work and the completion of two practical tasks, the maximum number of points that a graduate student can score is 55 points

2.3. Compilation of examination exams

The exam ticket contains three questions, the answer to each of which is evaluated according to the following rating points:

Criteria for evaluating answers to each question of the exam ticket

The completeness of the answer to each question of the examination ticket	***Points***
Perfectly	*15*
Very good	*13-14*
Fine	*10-12*
Satisfactorily	*7-9*
Enough	*6-7*
Unsatisfactorily	*<5*
Not admitted to the exam	*0*

The maximum number of points that a graduate student can receive as a result of successfully passing the exam is 45 points.

According to the rating scale(R),the maximum score is 100.

A prerequisite for admission to the exam is a rating of at least 30% of the rating scale (R), i.e. 30 points.

Distribution of rating points received by graduate students after studying the credit module and passing exams.

Content module	***Total points***
Lectures	*13*
Practical training	*26*
Performance of practical tasks	*16*
Semester control	
Exam	*45*
Together:	***100***

The procedure for enrolling missed lectures and practical classes: the graduate student independently prepares a synopsis of the missed lecture and/or practical class, answers the teacher's control questions.

The sum of the rating points received by the graduate student after mastering the discipline and passing the exam is transferred to the final grade according to the table:

Scores	***Rating***
95...100	*perfectly*
85...94	*very good*
75...84	*fine*
65...74	*satisfactorily*
60...64	*enough*
<60	*unsatisfactorily*
Admission conditions not met	*not allowed*

9. Additional information on the discipline (educational component)

Preliminary list of questions submitted for semester control.

1. Explain what we call the object of research. Consider the essence of the physical and mathematical model of the research object and their relationship.

2. Explain the principles of building a physical and mathematical model of the relative movement of dispersions in a continuous medium.

3. Explain the difference between the conceptual and mathematical formulation of the modeling problem

4. Consider the main methods of modeling. Form and principles of presentation of mathematical models.

5. To analyze the peculiarities of building mathematical models. List the main stages of creating a model

6. Analyze the main stages of creating a mathematical model for scientific research.

7. To explain the relationship between the statement of the research problem and the construction of the corresponding mathematical model.

8. Analyze the stages of building a mathematical model. Consider the basic principles of the formalization of a mathematical model, as a process of mapping a set of variable input parameters into a set of output parameters of the research object.

9. Explain with concrete examples what function is performed by a set of operators $\overline{F}$ *when formalizing the model.*

10. Explain what is meant by the concept of mathematical modeling. Consider the main stages of mathematical modeling with the use of a computer when conducting scientific research.

11. Explain the principles of building a mathematical model. Analyze sets of elements of a mathematical model - input variables $\overline{x}$ *and output parameters* $\overline{y}$*, internal constants* $\overline{U}_{ext}$ *and external* $\overline{U}_{int}$ *parameters. Show in what form these elements are included in the equation of the mathematical model.*

12. Analyze the features of the use of natural and mathematical modeling in conducting scientific research. Explain what is common and what is the fundamental difference between these modeling methods.

13. List the main advantages of mathematical modeling when conducting scientific research or engineering design. Explain the concept of natural and mathematical modeling

14. To substantiate the principle of combination and complementarity of natural (experimental) research methods and mathematical modeling methods. To show the expediency of the combined use of both modeling methods when conducting research.

15. Explain the fundamental difference between mapping input parameters of an object into output parameters, which is presented in natural and mathematical models. What, from this point of view, is the advantage of mathematical models and what role does the operator play $\overline{F}$*.*

16. Explain the statement that the purpose of modeling is to determine the structure of the operator $\overline{F}$*. In what form and in what form is the set of operators* $\overline{F}$ *used in mathematical models.*

17. Analyze the main requirements that are put forward when building a mathematical model. Completeness and simplicity of the model. A compromise between completeness and simplicity of the model.

18. Consider the principles of building simple and complex models depending on the complexity of the research object. Explain the difference in concepts of model simplicity not relative to model complexity, but relative to the form of the operator $\overline{F}$*.*

19. Describe the scope of the model, limits of model reliability, model adequacy; the possibility of modifying the model.

20. To justify the need to create sub-models (sub-models) as components of the basic model of the research object.

21. List the main factors by which models are classified. Explain the necessity and expediency of the classification of mathematical models

22. Consider the main types of models. Static and dynamic models. Deterministic and stochastic models.

23. Classification of models depending on their input parameters. What is the distribution of mathematical models by dimension (1-D, 2-D, 3-D models). Consider the feasibility of reducing the dimensionality of the model

24. Explain what the method of similarity and dimensionality analysis is when building a physical and mathematical model.

25. Explain the difference between stationary and dynamic processes from the point of view of the duration of the transition of the system to a new equilibrium state. Terms of use of dynamic and static models

26. Analyze methods of modeling dynamic and stationary processes. Name the features of modeling of quasi-stationary processes.

27. Give examples of linear and non-linear models. Consider the linearization method. Explain the definition of a linear equation and the principle of superposition.

28. Analyze numerical methods for solving nonlinear equations.

29. To substantiate existing approaches to the classification of mathematical models depending on the purpose of modeling. The purpose of using descriptive and optimization models.

30. Give examples of the use of optimization models to solve optimization problems according to one or more criteria.

39. Define the concept of continuous environment. Explain the possibility of simulating hydromechanical processes and mass transfer processes in dispersed media, extraction, emulsification, sorption, and other processes within the framework of solid medium mechanics.

32. Analyze the general conditions under which a substance with a discrete molecular structure, as well as heterogeneous mixtures, can be considered a liquid medium.

33. Explain under what conditions it is possible to describe the processes of heat transfer, the propagation of sound, ultrasonic, electromagnetic waves in a substance using the appropriate equations for a solid medium.

34. Analyze the basic equations of the mathematical model of a continuous environment. To explain the necessity of applying the mathematical model of the equation of state and the equation of continuity in the system of equations.

35. Define the concept of continuous environment. To explain the possibility of simulating hydromechanical and mass transfer processes in dispersed media, extraction, emulsification, sorption, and other processes within the framework of solid medium mechanics.

36. Analyze the continuity equation for an incompressible fluid in the form of differential and vector equations. What is a substantial time derivative?

37. State the substantial derivative operator. What does the substantial time derivative look like in the equations that describe stationary or non-stationary processes of fluid flow in channels?

38. Show the need to use computer modeling when solving nonlinear equations. Explain the concept of a dynamic system.

39. Analyze the methods of finding approximate values of integrals. Application of numerical methods of solving differential equations.

40. Explain, on the basis of which basic laws of nature, equations of transfer of the amount of motion, equations of energies (heat transfer) and equations of mass transfer are built.

41. Analyze the components of the Navier-Stokes equations when modeling stationary and non-stationary one-dimensional fluid flow in cylindrical channels.

42. Explain the general principle of deriving the Navier-Stokes equation by applying the standard method of describing elementary flows through the surfaces of an elementary cubic volume in three directions.

43. Show that when using the elementary cube method to derive the equation of motion, it is sufficient to apply the basic equations of Newton's second law and Newton's equation of viscosity in one-dimensional form.

44. Analyze the possibility of deriving the one-dimensional Navier-Stokes equation, for example, in the direction x*, if we consider the transfer of momentum only through two opposite surfaces* $ABCD$ *and -* $A'B'C'D'$*,* *45. Consider the basic principles of deriving the equation of heat conduction by the method of heat flow balance through the faces of an elementary cube. Give the general equation of thermal conductivity.*

46. Analyze the component equations of heat transfer in a continuous medium in vector form using the Laplace operator. Give a standard one-dimensional equation

48. Justify the equation of heat transfer in a fluid flow taking into account viscous dissipation. Give the appropriate heat transfer equation.

49. Explain the concept of dissipative function? Write the relation for the dissipative function for the one-dimensional heat conduction equation

50. Consider the features of the application of the heat conduction equation in a solid body and in convective flows of an incompressible fluid.

51. Explain the procedure for solving differential transfer problems. To analyze the main conditions of unambiguity, boundary conditions for heat transfer equations in a continuous medium.

52. Analytical and numerical methods of solving mathematical model equations. Consider the advantages of obtaining the solution of model equations in an analytical form.

53. Derive the equations of the relative movement of dispersions in a continuous liquid medium in the presence of centrifugal forces.

54. Analyze the component equations of the relative movement of gas dispersions (bubbles) when modeling biogas production processes.

55. Analyze the equation of the relative movement of dispersions in gas flows.

56. To analyze the equation of the relative movement of dispersions in a continuous medium in the "liquid-liquid" system.

57. State and analyze the basic equation of motion of dispersed particles in a continuous medium.

58. The main areas of application of the mathematical model of the relative movement of dispersions in a continuous medium.

59. Analyze the component equations of heat transfer in a continuous medium in vector form using the Laplace operator. Give a standard one-dimensional equation

60. To justify the need to use the equation of state in mathematical models of a continuous environment.

61. Explain the application of the standard procedure for solving a system of differential equations in mathematical models. To analyze the main conditions of unambiguity, boundary conditions for heat transfer equations.

Working program of the academic discipline (syllabus):

Folded*position, academic degree, academic title, full name*

Approved*department ___________ (protocol No. ___ from _____________)*

Agreed*Methodical commission of the faculty[1](protocol No. __ of _______)*

[1] Methodical council of the university – for general university disciplines.