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

Emblem of the departmen t (in the presence)

The name of the department that provides teaching

COURSE TITLE

Modeling of the state of a continuous medium

Work program of the discipline (Syllabus)

Details of the discipline

Level of higher education	***Third (educational and scientific)***
Branch of knowledge	*13 Mechanical engineering*
Specialty	*133 Industrial engineering*
Educational program	*ONP Branch engineering*
Discipline status	*Normative*
Form of study	*full-time (day) / full-time (evening) / part-time / remote / mixed*
Year of preparation, semester	*2nd year, autumn semester*
The scope of discipline	*4 (120)*
Semester control / control measures	*Examination*
Timetable	*3 hours per week (1 hour of lectures and 2 hours of practical classes)*
Language of instruction	*Ukrainian*
Information about course leader / teachers	Lecturer:*Ph.D., Prof. Ivanitsky GK,* Practical / Seminar: *Doctor of Technical Sciences, Prof. Ivanytsky GK*
Course placement	Link to a remote resource (Moodle, Google classroom, etc.)

Curriculum of the discipline

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

Description of the discipline.

Methods of mathematical modeling 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 object of study, its formalization and transformation into a mathematical model in analytical or numerical form, suitable for obtaining a final solution to the problem. The implementation of numerical analysis algorithms is usually carried out on the basis of modern computer technology using specialized software packages. But for this researcher must have the basics of mathematical modeling, the ability to develop adequate mathematical models, to modify them, because the use of specialized packages always involves the need to choose the optimal algorithm and ways to successfully implement it,

The course focuses on the close relationship between field modeling of objects and processes with experimental research on laboratory stands and mathematical modeling of these processes, which, on the one hand, provides an opportunity to verify the adequacy and reliability of the model, ways to further modify, and on the other hand - carrying out the detailed analysis of results of experiment and substantiation of ways of the further direction of laboratory researches, introduction of necessary changes in a technique of carrying out experiments

The subject of the discipline.

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

Mastering the methods of mathematical modeling involves not just mastering certain rules and methods of action in the algorithms of model building and choosing a method of decision, but the development of a unique style of thinking focused on analyzing the physical and mathematical essence of the phenomena. The development of modern technologies in the field of "Industrial Engineering" increasingly requires a graduate student, mechanical engineer of deep and systematic multidisciplinary training, attracting knowledge and experience gained in other disciplines of physics, mathematics and chemical technology.

The purpose of the discipline.

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

The set goals will allow graduate students to master the methods of mathematical modeling, 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 of building appropriate mathematical models. physical and mathematical modeling of the state of a continuous medium.

In accordance with the purpose of this discipline, the training of doctors of philosophy in the specialty 133 Industrial Engineering requires further development of the competencies formed in graduate students:

In accordance with the purpose of this discipline, the training of doctors of philosophy in the specialty 133 Industrial Engineering requires further development of the competencies formed in graduate students:

- know the fundamental principles of the theory of hydrodynamics, heat and mass transfer and the basic principles of thermodynamics;
- be able to formulate a scientific problem in the field of industrial engineering, substantiate working hypotheses for solving the problem;
- know the basic classes of mathematical models of continuous media, general methods of their construction on the basis of physical laws of conservation, corresponding to the equations of balance;
- to have skills of application of mathematical models of continuous environments for modeling of various physical and mechanical processes, to carry out the correct choice of model and to adapt it for modeling of behavior of object of research.

According to the requirements of the curriculum of the discipline "Modeling the state of a continuous environment" graduate students after mastering the materials of the lecture course must demonstrate the following nprogram learning outcomes:

- be able to develop and research conceptual mathematical and computer models of processes taking into account the properties of a continuous environment, to implement their mathematical solution, to analyze the results,
- to know modern methods of formalization of states of a continuous environment, the basic types of defining relations characterizing behavior and reaction of objects of research within the limits of the generalized models of continuous environments;

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

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

- be able to effectively apply methods of analysis, mathematical modeling, perform physical and computational experiments in the process of scientific research, solve complex problems in the field of mechanical engineering, conduct research and innovation, involving in-depth understanding of existing and creation of new holistic knowledge and practical implementation the results obtained;

2. Prerequisites and postrequisites of the discipline (place in the structural and logical scheme of education 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 a set of knowledge acquired by graduate students during bachelor's and master's degrees in the study of natural sciences and engineering in the field of "Mechanical Engineering". For successful mastering of this discipline it is necessary to have basic knowledge in the field of higher mathematics, physics, physical chemistry, theoretical bases 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 administrator level; have skills in the field of 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 sound judgments in solving complex scientific and technical problems in professional and research-innovative activities that involve a deep rethinking of existing and the creation of new holistic knowledge and fruitful professional practice.

3. The content of the discipline

Section 1 Fundamentals 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.

Section 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 methods of mathematical modeling in conducting research.

Topic 5.Stages of building physical and mathematical models. Determinants of building a mathematical model.

Topic 6.Statement of research and solution of computational problems. Formalization of a mathematical model.

Topic 7. Simulation of dispersion motion in a continuous medium.

Section 4. Mathematical models of a continuous medium

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

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

Section 5. Methods for deriving the basic equations of the model of a continuous medium

Topic 10. Differential equation of continuity.

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

Topic 12.Differential equation of energy conservation. Derivation of the thermal conductivity equation.

Topic 13 Procedure for solving differential equations.

4. Training materials and resources

Basic literature

Basic literature

1. Vanin VA Mathematical models and numerical methods in problems of continuum mechanics: teaching method. textbook for the course "Modern problems of mathematical and computer modeling" for students. machine-building and energy specials. / VA Vanin; Nat. tech. Kharkiv Polytechnic University - Kharkiv: NTU "KhPI", 2018. - 209 p.

2. Gritsyna O., Kondrat V. Thermomechanics of condensed systems taking into account the local displacement of mass: I. Fundamentals of the theory. –Lviv: Raster -7, 2017. –208 p.

3. Grinchenko VT, Mechanics of liquid, gas and plasma. // Encyclopedia of Modern Ukraine: electronic version [website] / Vol. editor: I.M. Dziuba, AI Zhukovsky, MG Zheleznyak and others. - Kyiv: Institute of Encyclopedic Research of the National Academy of Sciences of Ukraine, 2018. URL:http://esu.com.ua/search_articles.php?id=67464

4. Bilushchak Y., Gaivas B., Hera B. and others. Mathematical modeling of nonequilibrium processes in complex systems. Ed. E. Chapli. - Center for Mathematical Modeling of the Institute of Applied Problems of Mechanics and Mathematics. Ya. S. Pidstryhach of the National Academy of Sciences of Ukraine. Lviv: Raster - 7, 2019. – 256 p.

5. Bekas BO, Kapran ID, Szymanski VM Matlab in numerical methods. Using a mathematical package to solve applied problems. View. НЛТУУ. Lviv. 2016. -170.

6. Gaivas BI, Chaplya EY, Dmitruk VA Physical and mathematical modeling of drying of dispersed materials. –Lviv: Raster -7, 2018. – 146 p.

7. Semenova I.Yu. Mathematical models of solid medium mechanics Textbook Kyiv: Taras Shevchenko National University of Kyiv 2014.-82 s.

Additional literature

1. Samarsky, AA Mikhailov AP Mathematical modeling. Ideas. Methods. Examples. – M: Fizmatgiz, 2001. – 320 p.

http://samarskii.ru/books/book2001.pdf

2. Mechanics of continuous media.– 1. Mechanics of continuous media in engineering calculations: Text of lectures for students of specialties "Equipment of chemical industries and enterprises of building materials" / Compiled by: O.C. Sakharov, A. Ya. Karvatsky. – Kyiv: NTUU «KPI», 2013. – 231 p.

https://cpsm.kpi.ua/Doc/MSS-1.pdf

3. Khusainov D.Ya., Kharchenko II, Shatyrko AV Introduction to modeling of dynamic systems: Textbook. manual. Kyiv: Taras Shevchenko National University of Kyiv, 2010. – 130 p.

4. Myshkis AD Elements of the theory of mathematical models Ied. 3rd, ed.
M .: KomKniga, 2007. 92 s.

5. Pavlenko PM Fundamentals of mathematical modeling of systems and processes: textbook. manual. – Kyiv: Books. published by NAU, 2013. − 201 p.https://cpsm.kpi.ua/Doc/MSS-1.pdf

6. Introduction to mathematical modeling: uch. allowance. under ed. P.V. Coward. M .: Logos, 2007. – 440 p.

7. Kasatkin AG The main processes and devices of chemical technology: A textbook for universities.-10th ed. M .: LLC TID "Alliance", 2004.- 753 p.

8. Chubby VA Numerical methods. Theory and workshop in the MATLAB environment: textbook in 2 volumes. Sevastopol: Cherkasy CNTEI Publishing House. - T. I. −2007. – 412 s.−T. II. − 2008. – 762 p.

5. Methods of mastering the discipline (educational component)

Lectures.

Lectures are aimed at providing modern holistic knowledge in the discipline of "Modeling the state of a continuous environment", the definition of the current level of development of science in the field of modeling in conducting comprehensive research; presentation of new scientifically substantiated 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 research and engineering practice; ensuring the fruitful work of graduate students during the lecture; application of effective teaching methods, presentation of material and its mastering; education of professional qualities in graduate students and the development of creative thinking; formation of their scientific and practical interest in mastering the course material, the desire to work independently.

№ s / n	Title of the lecture topic, list of main questions, references to the literature and tasks on VTS.	Hours
1	***Natural and mathematical modeling. Objects of research.*** Definition of a mathematical model. Physical model. Properties of models. The purpose of modeling. Conceptual modeling.Intuitive modeling. Literature: [2] p.13-20, [3] p.6-9, [4] p.7-16, [5] p.6-21, [7] p.38-49, [8] pp.11-21. [13] 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 limits of reliability. Availability of communication and model management. Modification of the model. Literature: [3] p.10-12, [4] 7-16, [7] p.49-60, p.71-74, [8].	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 nonlinear 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. Dimension of the model. Literature: [1] p.11-25, [3] p.12-17, [4] p.17-34,: [5] p. 237-242, [6] pp.6-11, [8] 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. Multicriteria optimization problems .. The concept of structural model. Submodels (sub-models). Literature: [1] p.202-270, [7] p.67-71, [8] p.36-56, p. 142-180.	1
5	***Stages of building physical and mathematical models.*** Determinants 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: [4] p.35-45, p..78-92, [5] p.225-235, [7] p. 94-102, 154-162, [8] p.56-86.	1
6	***Statement of research and solution of computational problems.*** Statement of the problem of mathematical modeling. Formalization of a mathematical model. Computational experiment. Adequacy check. Analysis of simulation results. Physical paradoxes in modeling. The reasons for their occurrence. Literature: [4] p.104-140, [6] p.12-36, [7] p.38-42, p.88-112, [8] p.245-260.	1
7	***Simulation of dispersion motion in a continuous medium.*** Influence of mass forces and flow acceleration on the relative velocity of dispersions. Influence of density of dispersed and continuous phase. . Equation of motion of dispersed particles in a continuous medium. The main areas of application of the mathematical model. Literature: [5] p.149-162, [9] p. 176-181, pp.213-215, 224-226.	1
8	***Definition of a continuous environment***. The concept of continuum. Problems of research of a condition of continuous environments. Methods for modeling the state of continuous media. Basic	1

	hypotheses of mechanics of continuous media Basic equations of mechanics of continuous media. Equation of state. The continuity equation. Equation of transfer of momentum, energy and mass. Physical substantiation of equations. Literature: [2] p.20, p.60-66, [3] p.25-30, [6] p. 38-59.	
9	***Mathematical modeling based on the fundamental laws of nature.*** Classification of transfer mechanisms. Fick's law and diffusion. Fourier law and thermal conductivity. Newton's law and viscous friction. Derivation of local equations of balance from integral conservation laws. Writing balance equations in the representation of Euler and Lagrange. Literature: [1] p.11-15, 58-82, [2] 66-86, [3] p. 17-55, [6] pp.199-230.	***1***
10	***Differential equation of continuity.*** Preservation of mass of substance. with. 58-65. Differential operator. Scalar function gradient. Flow rate. Divergence of the vector field. Vector field rotor. Full derivative. Partial derivative. Substantial derivative. The continuity equation for compressible and incompressible fluid. Literature: [1] p. 58-65, [2] p. 66-70, [3] p.55-60, [6] p.38-62, [9] p.48-50.	***1***
11	***Differential equation of fluid motion or momentum equation.*** The law of conservation of momentum. Navier-Stokes equation. Transfer of the amount of motion in the elementary zone, in the elementary cell. Forms of writing the differential equation of motion. Equation of motion in Cartesian, cylindrical, spherical coordinate system. Literature: [1] p. 93-95, [2] p.94-110, [3] p.17-30, [5] p.148-176, [9] p. 52-64, [13] p. 585-630.	***1***
12	***Differential equation of energy conservation.*** The law of conservation of energy. Laplace equation. Derivation of the thermal conductivity equation. Motion of solid, liquid and gaseous bodies with phase transformations. Basic and standard equations of thermal conductivity in Cartesian, cylindrical and spherical coordinate system. Literature: [1] p. 66-76, [3] p.25, [5] p.225-365, [6] p. 138-180, [9] p. 260-310	***1***
13	***Procedure for solving differential equations.*** Conditions of unambiguity. Initial and boundary conditions.Computer implementation of mathematical models of systems. Information systems and computer programs for modeling technical systems. Modern application packages Literature: [1] p.70-78, [4] p. 164-174, [7] p.130-142, [10].	***1***
Hours in general		***13***

Practical training.

When studying the credit module, 2/3 of the classroom workload is assigned to practical classes. Practical classes on a particular topic of this discipline are aimed at consolidating the material presented in the lecture by considering specific examples, exercises and tasks on this topic. This allows graduate students to systematize and deepen theoretical knowledge about modern methods of developing a mathematical model, verifying its reliability and adequacy, methods of modifying the model if necessary to improve or simplify it. Emphasis is placed on the close relationship between the methods of field modeling on laboratory stands and mathematical modeling in a comprehensive scientific study. In practical classes in solving applied problems, graduate students master the skills to compose a system of differential equations of the model with boundary conditions and solve them by analytical methods or numerical methods using modern application packages. The practical lesson is conducted in a dialogue mode for educational discussions. In the course of employment the control interrogation of listeners on materials of previous lectures, their acquaintance with the literary sources on subjects of discipline is carried out.

№ s / n	*The name of the topic of the practical lesson, a list of basic questions, references.*	*Hours*
1	***Physical and mathematical modeling. Object of study. Mathematical formulation of the modeling problem*** Definition of the object of research. Definition of a mathematical model. The purpose of modeling. Basic assumptions. Properties of models. Literature: [2] p.13-20, [4] p.7-16, [7] p.38-49, [8] 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 limits of reliability. Availability of communication and model management. Modification of the model. Literature: [3] p.10-12, [4] 7-16, [7] p.49-60, p.71-74, [8].	***2***
3	***Types of mathematical models and methodology***. Examples of deterministic and stochastic models. Dimension of the model. Method of similarity and dimensional analysis in the construction of physical and mathematical models. 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 model implementation. Analytical and numerical methods. Graphic methods The concept of structural model. Submodels. Literature: [1] p.202-270, [7] p.67-71, [8] p.36-56, p. 142-180.	***2***
5	***Conceptual and mathematical formulation of the modeling problem***. Determinants of building a mathematical model. Methods of mathematical modeling .. The use of information technology. Standard models. Literature: [4] p.35-45, p..78-92, [5] p.225-235, [7] p. 94-102, 154-162, [8] p.56-86.	***2***
6	***Statement of research and solution of computational problems.*** Statement of the problem of mathematical modeling. Formalization of a mathematical model. Computational experiment. Adequacy check. Analysis of simulation results. Physical paradoxes in modeling. Literature: [4] p.104-140, [6] p.12-36, [7] p.38-42, p.88-112, [8] p.245-260.	***2***
7	***Simulation of dispersion motion 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. The movement of gaseous, liquid, solid dispersions in the gravitational field, in centrifuges. Soaring speed. Literature: [5] p.149-162, [7] p.94, [9] p. 176-181, pp.213-226.	***2***
8	***Methods for modeling the state of continuous media.*** Basic equations of mechanics of continuous media. Physical substantiation of equations. Equation of state. The continuity equation. Equation of transfer of momentum, energy and mass. Literature: [2] p.20, p.60-66, [3] p.25-30, [6] p. 38-59.	***2***
9	***Mathematical modeling based on the fundamental laws of nature.*** Classification of transfer mechanisms. Fick's law and diffusion. Fourier law and thermal conductivity. Newton's law and viscous friction. Derivation of local equations of balance from integral conservation laws. Writing balance equations in the representation of Euler and Lagrange. Literature: [1] p.11-15, 58-82, [2] 66-86, [3] p.17-55, [6] p.199-230.	***2***

10	***Differential equation of continuity.*** Preservation of mass of substance. Differential operator. Scalar function gradient. Full derivative. Partial derivative. Substantial derivative. The continuity equation for compressible and incompressible fluid. Literature: [1] p. 58-65, [2] p. 66-70, [3] p.55-60, [6] p.38-62, [9] p.48-50.	***2***
11	***Differential equation of fluid motion or momentum equation*** The law of conservation of momentum. Navier-Stokes equation. Transfer of the amount of motion in the elementary zone, in the elementary cell. Forms of writing the differential equation of motion. Equation of motion in Cartesian, cylindrical, spherical coordinate system. Literature: [1] p. 93-95, [2] p.94-110, [3] p.17-30, [5] p.148-176, [9] p. 52-64, [13] p. 52-64,	***2***
12	***Differential equation of energy conservation.*** The law of conservation of energy. Laplace equation. Derivation of the thermal conductivity equation. Basic and standard equations of thermal conductivity in Cartesian, cylindrical and spherical coordinate system. Motion of solid, liquid and gaseous bodies with phase transformations. The equation of thermal conductivity for a stationary solid. Equation of heat transfer in the flow of incompressible fluid. The equation of heat transfer in the flow taking into account the viscous dissipation. Literature: [1] p. 66-76, [3] p.25, [5] p.225-365, [6] p. 138-180, [9] p. 260-310	***2***
13	***Procedure for solving differential equations.*** Conditions of unambiguity. Initial and boundary conditions.Computer implementation of mathematical models of systems. Information systems and computer programs for modeling technical systems. Modern application packages Literature: [1] p.70-78, [4] p. 164-174, [7] p.130-142, [10].	***2***
Hours in general		***26***

6. Independent work of a student / graduate student

When teaching the discipline "Modeling the state of a continuous environment" independent work of the graduate student takes 75% of the time to study the credit module, taking into account the preparation for the exam. Independent work of graduate students includes preparation for classroom classes, performance of two individual tasks in the form of abstracts and elaboration 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 by detailed acquaintance with the relevant sections of the recommended basic and additional literature and independent scientific and informational search on their own initiative. The preparation of the graduate student for the next classroom classes involves the development of the material of previous lectures in the process of independent work.

№ s / n	**Type of work and names of topics submitted for self-study**	**Number of hours**
1	***Preparation for classroom classes.***	***40***
2	***Execution of individual practical tasks on the topic of the module.***	***12***
Elaboration of sections of the program and topics that are not taught in lectures.		
3	***Section 1 Fundamentals of physical and mathematical modeling.*** Basic concepts of mathematical modeling. References [1] p.11-25, [12] Ch.1, [14] p.7-38,	***3***
4	***Section 2. Classification of mathematical models.*** Linear and nonlinear models. Linear equations and the principle of superposition. References [8] p.245-310, [11]	***6***

5	***Section 3. Application of methods of mathematical modeling in conducting research.*** Construction of a mathematical model and computational experiment. Examples of mathematical models in physics, chemistry, biology References [14] p.38-81.	*4*
6	***Section 4.*** *Mathematical models of a continuous medium* Laws of conservation in the physics of continuous media. Equations of motion, variational principles and conservation laws. Writing balance equations in the representation of Euler and Lagrange. References [1] p.93-105, [2] p. 20-30, p. 66-71, [13] Vol.1, p. 279-300	*4*
7	***Section 5. Methods for deriving the basic equations of the model of a continuous medium*** Modeling of hydromechanical processes Literature [5] p.148-176 Modeling of heat exchange processes Literature [5] p. 178-220 Modeling of mass transfer processes Literature [5] p. 225-365	*6*
8	***Numerical methods for solving the equations of fluid mechanics and heat transfer.*** Application of the finite difference method to solve model equations. References [13] Part 1. Modern application packages Literature [7] p.130-150. [10].	*6*
9	***Exam preparation***	
Hours in general		***81***

Policy and control

7. Course policy (educational component)

Rules for attending lectures and practical classes;

Attendance at lectures and practical classes is a mandatory component of studying the material. At the lecture the teacher uses his own presentation material. Postgraduate 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 actions that are not related to the educational process.

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

Policy of deadlines, rearrangements and rules of encouragement;

Missed classes must be completed. The graduate student independently prepares the synopsis of the missed lecture or practical lesson, answers control questions to the teacher on materials of a theme of the missed lesson. Individual practical tasks should be performed carefully and on time. Fulfillment of these requirements provides an increase in the rating of the results of mastering the discipline.

Academic Integrity Policy;

The policy of the discipline is based on the norms of the legislation of Ukraine on academic integrity, the Code of Honor of NTTU "Kyiv Polytechnic Institute named after Igor Sikorsky and is determined by the system of requirements that the teacher imposes on the student when studying the discipline (rules of conduct, omissions, transfer, etc. .

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

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

Training time		Distribution of teaching hours				Control measures		
Loans	acad. year	Lectures	Practical	Lab. slave.	CPC	MCR	RR	Semester control
4	120	13	26	-	81	-	-	examination

The control of postgraduate students' knowledge 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.

The following is taken into account during the evaluation:

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

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

2. Scoring criteria:

2.1. Work in the classroom:

- fruitful work - 1 point;
- passive work or absence from class - 0 points.

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

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

Completeness and timeliness of the task	**Bali**
Full execution, proper registration of work, submission in due time	**8**
The work was done on time, but there are some shortcomings in the work	6
Pthe turnover was made in a timely manner, but with significant shortcomings	3-4
The work was submitted later than the deadline	4
The work was performed late with certain shortcomings	3
The work was performed late with significant shortcomings	1
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 educational work and the implementation of two practical tasks, the maximum number of points that a graduate student can score is 55 points

2.3. Passing exam exams

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

Criteria for evaluating the answer to each question of the examination ticket

Completeness of the answer to each question of the examination ticket	**Bali**
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 passing the exam is 45 points.

According to the rating scale (R), the maximum sum of points is equal to 100.

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

Distribution of rating points that graduate students receive after studying the credit module and passing exams.

Content module	The sum of points
Lectures	13
Practical training	26
Execution of practical tasks	16
Semester control	
Examination	45
Together:	**100**

The order of enrollment of missed lectures and practical classes: the graduate student independently prepares a synopsis of missed lectures and / or practical classes, answers control questions to the teacher.

The sum of the rating points obtained 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
lmission conditions are 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 study. Consider the essence of the physical and mathematical model of the object of study and their relationship.

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

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

4. Consider the basic methods of modeling Form and principles of representation of mathematical models.

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

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

7. Explain the relationship between the problem of research and the construction of an appropriate mathematical model.

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

9. Explain on specific examples, which function is performed by many operators $\overline{F}$ when formalizing the model.

10. Explain what is meant by mathematical modeling. To consider the main stages of mathematical modeling with the use of a computer in scientific research.

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

12. To analyze the features of the application of full-scale and mathematical modeling in scientific research. Explain what is common and what is the fundamental difference between these modeling methods.

13. List the main advantages of mathematical modeling in research or engineering design. Explain the concept of full-scale and mathematical modeling

14. To substantiate the principle of combination and complementarity of full-scale (experimental) research methods and methods of mathematical modeling. To show expediency of joint application of both methods of modeling at carrying out researches.

15. Explain the fundamental difference between the mapping of the input parameters of the object in the output parameters, which is presented in full-scale and mathematical models. What, from this point of view, is the advantage of mathematical models and what role the operator plays $\overline{F}$.

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 the set of operators $\overline{F}$ used in mathematical models.

17. Analyze the basic requirements for building a mathematical model. Completeness and simplicity of the model. A compromise between completeness and simplicity of the model.

18. Consider the principles of construction of simple and complex models depending on the complexity of the object of study. Explain the difference between the concepts of model simplicity not in relation to the complexity of the model, but in relation to the shape of the operator $\overline{F}$.

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

20. To substantiate the need to create submodels (submodels) as components of the basic model of the object of study.

21. List the main factors by which the classification of models. Explain the need and feasibility of classifying 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). To consider conditions of expediency of reduction of dimension of model

24. Explain what is the method of similarity and dimensional analysis in the construction of physical and mathematical models.

25. Explain the difference between stationary and dynamic processes in terms of the duration of the transition of the system to a new equilibrium state. Terms of application of dynamic and static models

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

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

28. Analyze numerical methods for solving nonlinear equations.

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

30. Give examples of application of optimization models to solve optimization problems on one or more criteria.

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

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

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

34. Analyze the basic equations of the mathematical model of a continuous medium. Explain the need to apply in the system of equations a mathematical model of the equation of state and the equation of continuity.

35. Define the concept of a continuous environment. Explain the possibility of modeling hydromechanical processes and mass transfer processes in dispersed media, extraction, emulsification, sorption and others 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. Give the operator of the substantial derivative. What does a substantial time-time derivative look like in equations that describe stationary or nonstationary fluid flow processes in channels?

38. Show the need for computer simulation in solving nonlinear equations. Explain the concept of a dynamic system.

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

40. Explain on the basis of which the basic laws of nature are built the equations of transfer of momentum, the equation of energy (heat transfer) and the equation of mass transfer.

41. Analyze the components of the Navier-Stokes equation in the simulation of stationary and nonstationary 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 surface of an elementary cubic volume in three directions.

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

44. Analyze the possibility of deriving a one-dimensional Navier-Stokes equation, for example, in the direction x, if we consider the transfer of the amount of motion through only two opposite surfaces $ABCD$ and - $A'B'C'D'$,,

45. Consider the basic principles of deriving the equation of thermal conductivity by the method of balance of heat fluxes through the faces of an elementary cube. Give the general equation of thermal conductivity.

46. Analyze the components of the heat transfer equation 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 the fluid flow, taking into account the viscous dissipation. Give the corresponding heat transfer equation.

49. Explain the concept of dissipative function? Write a relation for the dissipative function for a one-dimensional equation of thermal conductivity

50. To consider features of application of the equation of thermal conductivity in a firm body and in convective streams of incompressible liquid.

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

52. Analytical and numerical methods for solving the equations of a mathematical model. Consider the advantages of obtaining solutions of model equations in analytical form.

53. Derive the equation of relative motion of dispersions in a solid liquid medium in the presence of centrifugal forces.

54. Analyze the components of the equation of relative motion of gas dispersions (bubbles) in modeling the processes of biogas production.

55. Analyze the equation of relative motion of dispersions in gas streams.

56. Analyze the equation of relative motion of dispersions in a continuous medium in the system "liquid-liquid".

57. Give and analyze the basic equation of motion of dispersed particles in a continuous medium.
58. The main directions of application of the mathematical model of the relative motion of variances in a continuous medium.
59. Analyze the components of the heat transfer equation in a continuous medium in vector form using the Laplace operator. Give a standard one-dimensional equation
60. To substantiate the need to apply the equation of state in mathematical models of a continuous medium.
61. Explain the application of the standard procedure for solving a system of differential equations in mathematical models. Analyze the basic conditions of unambiguity, boundary conditions for heat transfer equations.

Work program of the discipline (syllabus):

FoldedProfessor of the Department of MAHNV, Ph.D. Ivanytsky George Konstantinovich

Approved at the meeting of the Department of Machines and Apparatus of Chemical and Oil Refining (Protocol № 26 of 19 June 2021)

Agreed metodic commission of the Faculty of Engineering and Chemistry (Protocol № 11 of June 25, 2021)