



Syllabus Course Program

Theoretical foundations for modeling physical processes. 1

Specialty

113 – Applied mathematics

Institute

Institute of Computer Modeling, Applied Physics
and Mathematics

Educational program

Computer and mathematical modeling

Department

Mathematical modeling and intelligent computing
in engineering (161)

Level of education

Bachelor's level

Course type

Special (professional), Mandatory

Semester

5

Language of instruction

English

Lecturers and course developers

**First name and surname**

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[More about the lecturer on the department's website](#)

General information

Summary

“Theoretical Foundations of Modeling Physical Processes” is one of the fundamental disciplines in the preparation of a bachelor's degree in applied mathematics. Part one includes the theory of elasticity, and part two is devoted to the theory of plates and shells. The applied significance of these subjects is due to the fact that most disasters that occur are associated with insufficient strength of structures, when their individual elements cease to perform their functions under the influence of load and lose their strength. The knowledge of such phenomena and the ability to resist them is mandatory for specialists conducting applied research in various fields of mechanics of solid deformable bodies.

Course objectives and goals

The goals of the program are to equip students with the ability to solve complex specialized problems and practical problems of applied mathematics in professional activities or in the process of study, which involves the application of mathematical theories, methods, algorithms, information technologies and specialized software.

Format of classes

The training includes lectures, practical classes, mandatory homework and a course project. The final control is an exam.

Competencies

- Ability to use and adapt mathematical theories, methods and techniques to prove mathematical statements and theorems.
- Ability to perform tasks formulated in mathematical form.
- Ability to choose and apply mathematical methods for solving applied problems, modeling, analysis, design, management, forecasting, decision-making.
- Ability to conduct mathematical and computer modeling, analysis and data processing, computational experiment, solving formalized problems using specialized software.
- Ability to formulate a mathematical statement of a problem, based on the statement in the language of the subject area, and choose a method of solving it that ensures the required accuracy and reliability of the result.
- Ability to create mathematical models of real objects and processes, develop methods for solving problems and evaluate the adequacy of results

Learning outcomes

- Demonstrate knowledge and understanding of the basic concepts, principles, theories of applied mathematics and use them in practice.
- Formalize problems formulated in the language of a particular subject area; formulate their mathematical formulation and choose a rational method of solution; solve the obtained problems by analytical and numerical methods, evaluate the accuracy and reliability of the results.
- To master the basic methods of developing discrete and continuous mathematical models of objects and processes, analytical study of these models for the existence and uniqueness of their solution.
- Be able to conduct practical research and find solutions to incorrect problems.
- Use specialized software products and software systems of computer mathematics in practical work.
- To be able to create mathematical models of real objects and processes, develop methods for solving problems and evaluate the adequacy of results

Student workload

The total volume of the discipline is 150 hours (5 ECTS credits): lectures - 32 hours, practical classes - 32 hours, independent work - 86 hours.

Course prerequisites

Mathematical analysis, Linear algebra, Differential equations (basic concepts), Programming, Theoretical mechanics.

Features of the course, teaching and learning methods, and technologies

The educational process includes: lectures with the use of computer information tools; practical classes, independent work. The lecture course is taught using problem-based learning methods through the application of such forms of learning as thematic and problem-based lectures. The purpose of such lectures is to develop students' logical and independent understanding of the material.

Independent work of students includes: preparation for practical classes, study of recommended scientific literature, writing reports on mandatory work.

Program of the course

Topics of the lectures

Introduction

The subject of the theory of elasticity. Place among the disciplines of mechanics of deformable body. Practical importance of the methods of elasticity theory. Brief historical background. Basic hypotheses and principles of the theory of elasticity. Model of a perfectly elastic body.

Topic 1: Theory of stress state.

- 1.1. External volumetric and surface forces.
- 1.2. Internal stresses. The method of sections. Total, normal and tangential stresses on an arbitrary site.
- 1.3. Coordinate stresses. Relationship of stresses on inclined platforms with coordinate stresses.
- 1.4. Differential equations of equilibrium. The law of parity of tangential stresses. Static boundary conditions.

Topic 2. Study of the stress state at a point.

- 2.1. Lamé ellipsoid. Cauchy stress surface. Principal sites and principal stresses.
- 2.2. Determination of the position of principal sites and values of principal stresses. Stress state invariants.
- 2.3. Formulas for transforming coordinate stresses when rotating the coordinate system.
- 2.4. Determination of maximum tangential stresses.

Topic 3. Geometric theory of deformation. 3.1. Lagrangian and Eulerian description of a continuous medium. Material coordinates.

- 3.2. Displacement vector and its projections. Components of small deformation.
- 3.3. Relative displacement tensor and strain tensor. The main directions of the strain tensor.
- 3.4. Relation of displacements to deformations. Cauchy's formulas.
- 3.5. Volumetric deformation. Rotation vector.
- 3.6. Conditions of joint deformation.

Topic 4. Physical relations of the theory of elasticity.

- 4.1. Thermodynamics of elastic deformation. Green's formulas.
- 4.2. Generalized Hooke's law. Types of symmetry of elastic properties. Hooke's law for an orthotropic body.
- 4.3. Hooke's law for an isotropic body in direct and inverse form.
- 4.4. Elastic constants. Limitations on the numerical values of elastic constants.

Topic 5. Complete system of equations of the theory of elasticity; boundary conditions.

- 5.2. Basic problems of the theory of elasticity. Direct and inverse methods of solution. Semi-inverse method of Saint-Venant.
- 5.3. Solving problems of the theory of elasticity in displacements and stresses. Lamé and Beltrami-Mitchell equations.
- 5.4. General properties of solutions of problems of the theory of elasticity in the absence of bulk forces.
- 5.5. Theorem on the uniqueness of the solution of the problem of elasticity. Flat problem of elasticity.

Topic 6. Plane problem of elasticity theory.

- 6.1. Plane deformation and plane stress state. The Airy stress function. Basic biharmonic equation of the plane problem.
- 6.2. Solution of a plane problem in algebraic polynomials. Solution of a plane problem in the form of Ribier and Filon.
- 6.3. Plane problem of elasticity in polar coordinates.
- 6.3. Axisymmetric plane problems. Lamé's problem. Cylinders under pressure.
- 6.4. Calculation of rotating disks
- 6.4. Stress concentration in a plate with a small hole under unilateral tension (Kirsch's problem).

Topic 7. Variational formulations and methods for solving problems of the theory of elasticity.

- 7.1. Variational principles and functionalities. Lagrange's variational principle. The principle of minimum additional work, Castigliano functional.
- 7.2. Direct variational methods. Ritz and Bubnov-Galerkin methods.

Topics of the workshops

Topic 1: Relation of stresses on inclined platforms to coordinate stresses

Topic 2. Static boundary conditions of necessity.

Topic 3: Determination of the position of the main platforms and the values of the main stresses.

Topic 4. Direct and inverse methods for solving problems of elasticity theory.

Topic 5. Lamé's problem. Cylinders under pressure.

Topic 6. Calculation of rotating disks

Topic 7. Calculation of compound disks

Topics of the laboratory classes

Self-study

Completion of independent works, current control and module works. Implementation of mandatory work

Course materials and recommended reading

1. Timoshenko S.P. Theory of elasticity – New York.
2. J.R. BARBER. Elasticity. Kluwer Academic Publishers.
3. L.D.Landau, E.M. Livshits. Theory of elasticity.Pergamon Press.
4. A.I. Lurie. Theory of elasticity. Springer-Verlag Berlin Heidelberg.
5. Krzysztof Wilmanski. Fundamentals of Solid Mechanics. (ROSE School), Pavia, Italy

Assessment and grading

Criteria for assessment of student performance, and the final score structure

To assess a student's performance, a point accumulation system is used. Maximum number of points for:

- independent work 5 points,
- control work 10 points,
- modular test 15 points.
- mandatory homework 20 points.

As an alternative to the cumulative point system, it is possible to take a written exam

Grading scale

Total points	National	ECTS
90–100	Excellent	A
82–89	Good	B
75–81	Good	C
64–74	Satisfactory	D
60–63	Satisfactory	E
35–59	Unsatisfactory (requires additional learning)	FX
1–34	Unsatisfactory (requires repetition of the course)	F

Norms of academic integrity and course policy

The student must adhere to the Code of Ethics of Academic Relations and Integrity of NTU "KhPI": to demonstrate discipline, good manners, kindness, honesty, and responsibility. Conflict situations should be openly discussed in academic groups with a lecturer, and if it is impossible to resolve the conflict, they should be brought to the attention of the Institute's management.

Regulatory and legal documents related to the implementation of the principles of academic integrity at NTU "KhPI" are available on the website: <http://blogs.kpi.kharkov.ua/v2/nv/akademichna-dobrochesnist/>

Approval

Approved by

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