Syllabus
Course Program

Nonlinear Mechanics of Solid Deformed Body

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
Master's level (1 year 4 months)

Course type
Special (professional), Mandatory

Semester
2

Language of instruction
English

Lecturers and course developers

Gennadiy Lvov
Gennadiy.Lvov@khpi.edu.ua
professor, doctor of technical sciences
Scopus: Scopus Author ID: 6506190655
ORCID: http://orcid.org/0000-0003-0297-9227
ResearcherID: U-8774-2017

More about the lecturer on the department's website

General information

Summary

"Nonlinear mechanics of a solid deformed body" is one of the fundamental disciplines in the preparation of a master's degree in applied mathematics. The first part includes the theory of elasticity, the second part is devoted to the theory of plates and shells. The applied value of these items is due to the fact that most of the disasters that occur are related to the insufficient strength of structures, when their individual elements stop performing their functions under the influence of load and lose their strength. Knowledge of such phenomena and the ability to resist them is mandatory for specialists who conduct applied research in various fields of the nonlinear mechanics of a solid deformed body.

Course objectives and goals

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

Format of classes

Lectures, practical classes,
consultations, self-study. Final control in the form of an exam.

Competencies

GC7. Ability to think abstractly, analyse and synthesise.
PC2. Ability to conduct scientific research aimed to develop new and adapt existing mathematical and computer models to study various processes, phenomena and systems, conduct appropriate experiments and analyse the results.
PC4. Ability to develop and research mathematical and computer models, conduct computational experiments and solve formalised problems using specialised software.
PC9. The ability to mathematically formalise the formulation of scientific and practical problems, to choose a mathematical analytical or numerical method of its solution, which ensures the required accuracy and reliability of the result.
PC10. Ability to develop mathematical methods and algorithms for computer modelling of nonlinear physical phenomena and processes in innovative technological systems.
PC12. Ability to identify the essence of scientific and technical problems in professional activities, to apply appropriate mathematical models for the study of mechanical objects and processes.

Learning outcomes

LO4. Build mathematical models of complex systems and choose methods of their research, implement the built models in software and check their adequacy using computer technologies.
LO16. Be able to develop mathematical methods and algorithms for computer modelling of nonlinear physical phenomena and processes in innovative technological systems.

Student workload

The total volume of the discipline is 90 hours. (3 ECTS credits): lectures – 16 hours, laboratory work – 16 hours, independent work – 58 hours.

Course prerequisites

Knowledge, skills, and previous courses that are necessary for successful course completion.

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

The educational process includes: lectures using computer and information tools; practical classes, independent work. When teaching the lecture course, methods of problem-based learning are applied by applying such forms of learning as thematic and problem-based lectures. The purpose of such lectures is to develop students' logical and independent understanding of material.

Practical classes of meaningful modules are planned for each topic, include preparation for practical classes according to the specified plan; execution of control tasks; review of scientific publications on the selected issue. The following forms and methods of teaching are used: explanation, discussion, debate, writing theses, creating presentations, forming individual components of scientific works.

Students' independent work includes: preparation for practical classes, study of recommended scientific literature, writing reports, preparation for modular tests and assessment. Tasks of students' independent work are considered completed if they: are submitted within the specified time and are fully completed (reveal the topic of the task); do not have logical and calculation errors.

Program of the course

Topics of the lectures

Topic 1.
1.1. Material description of continuous environment.
1.2. Movement. The vector of displacement and speed of movement of a point.

Topic 2. Deiormation. Gradients of deformation and displacements.
Green and Cauchy strain tensors. Logarithmic measures of deformation

Topic 3. Generalized deformation tensors and their main values.
Geometric equations.

Topic 4. Small deformation. Relative volume change during deformation. Cauchy formulasTopic 5. Mathematical statement of the problems of the theory of elasticity.

Topic 5. External forces. Equilibrium equations in projections onto local bases of the deformed state5.3. Solving problems of the theory of elasticity in displacements and stresses. Lamé and Beltrami-Mitchell equations.
Topic 6. Equilibrium equation in the initial basis. Piola-Kirghoff stress tensor

Topic 7. Potential energy of deformations.
Energy stress tensor

Topic 8. Examples of deformed states. Affine transformation. Flat displacement field.

Topics of the workshops

Topic 1. Fundamentals of tensor algebra in oblique angular coordinates. Covariant and contravariant components.

Topic 2. Approximation of deformation diagrams according to different models of materials.

Topic 3. Modeling of sample stretching at large deformations in the ANSYS software complex.

Topic 4. Modulation of nonlinear deformation in software complexes
Polynomial model of the general form

Topic 5. Mooney-Rivlin model of hyperelastic material.

Topic 6. Numerical analysis of the deformation of thick-walled pipes made of hyperelastic materials.

Topic 7. Modeling of deformation of rubber shock absorbers

Topic 8. Numerical analysis of pneumatic shock absorbers.

Topics of the laboratory classes

Self-study

Preparation for practical classes. Completion of mandatory homework

Course materials and recommended reading

Basic literature

1. Lurie A. I., Nonlinear Theory of Elasticity, Paperback: North Holland, 2012. – 632p.
2. Божидарник В. В., Сулим Г. Т. Елементи теорії пружності, Львів: Світ,1994. — 560 с.
3. Nonlinear Elasticity: Theory and Applications (London Mathematical Society Lecture Note Series No 282) / Editors Y.B. Fu, R.W. Ogden. Cambridge: Cambridge University Press, 2001. XI – 525 p.
4. Truesdell C., Noll W. The Non-Linear Field Theories of Mechanics. Third Edition. Berlin, Heidelberg, New York: Springer-Verlag, 2004. – 602 p.

Additional literature

1. Bar-Sinai Y., Librandi G., Bertoldi K., Moshe M. Geometric charges and nonlinear elasticity of two-dimensional elastic metamaterials// Northwestern University, Evanston, 2020. – 10195 – 10202p.

2. Zeidler E. Basic Equations of Nonlinear Elasticity Theory / Nonlinear Functional Analysis and its Applications. IV: Applications to Mathematical Physics, 1988. Springer - Verlag New York, Inc. P. 158 – 232.

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	Date	
	Date August 30, 2023	Head of the department Oleksii VODKA
	Date August 30, 2023	Guarantor of the educational and professional program (1 year 4 months) Oleksiy LARIN