Syllabus
Course Program

Theoretical and Analytical Mechanics

Specialty
113 Applied Mathematics

Institute
Institute of Computer Modeling, Applied Physics and Mathematics

Educational program
Computer and Mathematical Modeling

Department
Theoretical Mechanics and Strength of Materials (166))

Level of education
Bachelor's level

Course type
Special (professional), Mandatory

Semester
3

Language of instruction
English

Lecturers and course developers

First name and surname

Denys Lavinskiy

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Doctor of Technical Sciences, Head of the Department of Theoretical Mechanics and Strength of Materials of NTU "KhPI", Professor

Author and co-author of more than 120 scientific and educational publications. Leading lecturer on the courses "Theoretical and Analytical Mechanics", "Theoretical Mechanics" (in Ukrainian and English), "Strength of Materials" (in English)
More about the lecturer on the department's website
https://web.kpi.kharkov.ua/teormeh/en/lavinskii-denis-vladimirovich/

General information

Summary

The course "Theoretical and Analytical Mechanics" is a fundamental physical and mathematical discipline, on which the professional activity of specialists of any technical profile is based. The study of this course ensures the formation of a modern scientific picture of the world in the future specialist, lays the foundations and develops the skills of abstraction, idealization and modeling. Particular attention is paid to mathematical modeling of processes and phenomena related to mechanical Motion and mechanical interaction of material objects, which has applied application to engineering analysis and synthesis. The course focuses on the justification and correct application of relevant mathematical models in relation to various types of mechanical motion and mechanical interaction. Mastering the essence and content of laws, understanding the nature of physical laws that take place in technical phenomena and processes, will provide an opportunity to consciously set and solve both theoretical and applied engineering problems that may arise in practice. As a result of studying the course "Theoretical and Analytical Mechanics", students should develop the ability to formulate, mathematical modeling and solve various engineering problems.

Course objectives and goals

Formation of certain knowledge and necessary competencies in the student that will allow in their professional activity to formulate, solve and generalize practical problems using the concepts, laws and methods of mechanics and special applied methods of mathematical and computer sciences.

Format of classes

Lectures, practical classes, self-study, consultations. Final control: exam.

Competencies

PC 02. Ability to perform tasks formulated in mathematical form.
PC 14. Ability to formulate a mathematical formulation of the problem, based on the statement in the language of the subject area, and choose a method for solving it that provides the necessary accuracy and reliability of the result.

Learning outcomes

LO 03. Formalize tasks 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 obtained.

Student workload

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

Course prerequisites

To successfully complete the course, you must have knowledge and practical skills in the following disciplines: "Mathematical Analysis", "Physics", "Analytical Geometry", "Linear Algebra".

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

The curriculum in the discipline "Theoretical and Analytical Mechanics" for students provides for participation in lectures, practical classes, individual calculation and graphic tasks, self-study of lecture material and topics of practical classes, self-study of issues not taught in lectures. During the semester, students are offered to complete tests. The final stage of studying the discipline is passing the exam. In the study of the discipline, a combination of types of educational work with methods and forms of activating the cognitive activity of students to achieve the planned learning outcomes and the formation of competencies are used.
To achieve the goal of training according to the work plan of the discipline, the following activities are implemented:
• self-study of the theoretical material of the discipline using Internet resources, methodological developments, special educational and scientific literature;
• teaching the material using a projection monitor, distance learning;
• consolidation of theoretical material in practical classes.

Program of the course

Topics of the lectures

Topic 1. Introduction. Theoretical mechanics and its place in the natural sciences. Subject, objects, tasks and methods of kinematics. mathematical methods of specifying the motion of a particle: vector, coordinate, natural.
Topic 2. Kinematics of a rigid body. Euler's formula, acceleration of points of a rigid body in planar and arbitrary motion. Instantaneous center of the velocity and how to find it.
Topic 3. Resultant (Complex) motion of particle and rigid body.
Topic 4. Vector measures of forces. Moment of force with respect to a point and an axis. Types of force systems (planar and spatial). The principal vectors of the system of forces.

Topic 5. Constraints and reactions of constraints. Vector and scalar equations of equilibrium of bodies under the action of spatial and planar systems of forces.
Topic 6. Newton's Laws and the equations of motion in the dynamics of a particle.
Topic 7. Measures of motion of material systems of bodies. Determination of vector and scalar measures of motion of bodies: momentum, angular momentum, kinetic energy, power and work of forces.
Topic 8. The first fundamental law of mechanics is the law of balance of the momentum a body. Center of mass. Theorem on the motion of the center of mass.
Topic 9. The second fundamental law of mechanics is the law of balance of angular momentum (kinetic momentum). Constant inertia tensor. Axial and centrifugal moments of inertia. Calculation of moments of inertia with respect to arbitrary axes. Principal axes and principal moments of inertia.
Topic 10. Differential equation of translational motion, rotational motion about a fixed axis, plane-parallel motion, arbitrary motion of a rigid body. Motion of the physical pendulum.
Topic 11. The third fundamental law of mechanics (the law of energy balance). The kinetic energy of a material solid. Koenig's theorem. Theorems on the change of kinetic energy.
Topic 12. Analytic mechanics fundamentals. The concept of real and virtual motions. General concepts about constraints, their mathematical description.
Topic 13. The concept of generalized coordinates and generalized forces. Potential energy, force function, Rayleigh function. Lagrange principle.
Topic 14. The Lagrange equation of the second kind. Their application to the analysis of the motion of mechanical systems.
Topic 15. The concept of inertial forces. D'Alembert's principle, kinetostatics method. D'Alembert-Lagrange principle, general equation of dynamics.
Topic 16. Oscillation of a mechanical system with one degree of freedom. Eigen, attenuating and forced oscillations. Beats. Resonance.

Topics of the workshops

Topic 1. Determination of kinematic characteristics of particlemotion by coordinate and natural methods of defining its motion.
Topic 2. Determination of kinematic characteristics of motion of points and bodies in the mechanisms of transformation of the simplest motions.
Topic 2. Determination of kinematic characteristics of motion of points and bodies in the mechanisms of transformation of the simplest motions.
Topic 4. Determination of the absolute velocity and absolute acceleration of a point in its complex motion.
Topic 5. Determination of reactions of bonds of rigid bodies under the action of a concurrent and planar system of forces.
Topic 6. Determination of reactions of bonds of rigid bodies under the action of a spatial system of forces.
Topic 7. Determination of reactions of supports of a composite structure under the action of a plane system of forces.
Topic 8. Solution of the second problem of point dynamics in rectilinear and curvilinear motions. Integration of differential equations of motion of a particle.
Topic 9. Solving problems of dynamics of a mechanical system using theorems on changing the amount of motion of a system.
Topic 10. Solving problems of dynamics of a mechanical system using theorems on the motion of the center of mass of the system and the laws of conservation of the amount of motion and motion of the center of mass of the system.
Topic 11. Solving problems of system dynamics using the angular momentum change theorem.
Topic 12. Investigation of the motion of a mechanical system by means of the theorem on the change of kinetic energy and the law of conservation of total mechanical energy.
Topic 13. Determination of kinematic characteristics of elements of mechanical systems using the theorem of change in kinetic energy.
Topic 14. Solving problems of dynamics of mechanical systems using lagrange equations of the 2nd kind.
Topic 15. Application of the kinetostatics method for the compilation of differential equations of motion of a rigid body and a mechanical system.
Topic 16. Examples of solving problems of mechanical system dynamics using the general equation of dynamics.

Topics of the laboratory classes

Laboratory works within the discipline is not provided.

Self-study

The course involves individual calculation and graphic work on the topics: "Determination of kinematic and static characteristics of the motion of points and bodies of a mechanical system" and "Study of the motion of a mechanical system using the theorem on the change of kinetic energy and Lagrange equations of the 2nd kind".
Additional self-study materials are also recommended for students.

Course materials and recommended reading

Basic literature
1. Shtanko, P. K., et al. "Theoretical mechanics. Study guide." (2021).
2. Mishchenko, I. V. "Theoretical Mechanics: Synopsis of Lectures." (2023).
3. Shtefan, N. I., and V. M. Fedorov. "Theoretical mechanics. Dynamics and analytical mechanics. Synopsis of lectures." (2022).
4. Shtefan, N. I., and V. M. Fedorov. "Theoretical mechanics. Statics. Kinematics: synopsis of lectures." (2021).
5. Dolgov, A. M. "Theoretical Mechanics. Dynamics." (2012).
6. Anishchenko, H. O., and D. V. Lavinskyi. "Particle kinematics." (2022).
7. Anishchenko, H. O., and D. V. Lavinskyi. "Kinematics of the simplest movements of a rigid body." (2024).
8. Anishchenko, H. O., and D. V. Lavinskyi. "Dynamics of a Particle." (2024).

Additional literature.
1. Fetter, Alexander L., and John Dirk Walecka. Theoretical mechanics of particles and continua. Courier Corporation, 2003.
2. Santilli, Ruggero Maria. Foundations of theoretical mechanics I: The inverse problem in Newtonian mechanics. Springer Science & Business Media, 2013.
3. Skalmierski, Bogdan. Mechanics. Elsevier, 2013.
4. Hrabovsky, George, and Leonard Susskind. Classical mechanics: the theoretical minimum. Penguin UK, 2020..
5. Fetter, Alexander L., and John Dirk Walecka. Nonlinear mechanics: a supplement to theoretical mechanics of particles and continua. Courier Corporation, 2006.
6. Murray, R. Spiegel. "Theory and Problems of Theoretical Mechanics (Schaums Outline)." (2024).

Assessment and grading

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

100% of the final grade consists of the results of the assessment in the form of an exam (40%) and the current assessment (60%).

Exam: written assignment (2 theory questions + solving 2 problems) and oral report.

Current assessment: 4 online tests and two calculation and graphic works (20% each).

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

31.08.23

Date, signature

Head of the department
Denys LAVINSKIY

Guarantor of the educational program
Gennadiy LVOV