Syllabus
Course Program

Differential Equations

Specialty
113 - Applied mathematics

Institute
IBE of Computer Modeling, Applied Physics and Mathematics

Educational program
Computer and mathematical modeling

Department
Applied Mathematics

Level of education
Bachelor's degree

Course type
Mandatory (*SP 9)*

Semester
3

Language of instruction
English

Lecturers and course developers

Yuri Mikhlin

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Doctor of Physical and Mathematical Sciences, Professor, Professor of the Department of Applied Mathematics

Researcher and educator with over 50 years of teaching, theoretical, and practical experience in the field of nonlinear dynamics, theory of nonlinear normal modes of oscillations, stability theory of motion, dynamics of thin-walled elastic systems, vibration damping, etc. Author of over 300 scientific publications and co-author of 6 monographs. Has frequently given talks and lectures at universities in various countries and at leading international conferences. Main courses: Special Chapters of Higher Mathematics, Differential Equations, Linear Algebra, Stability of Dynamic Systems.
More about the lecturer on the department's website

General information

Summary

The course on differential equations provides the knowledge necessary for the theoretical and practical training of bachelors and masters in solving many theoretical and engineering problems that arise in vibration theory, physical process modeling, static calculations, strength and dynamics of machines and mechanisms, optimization tasks, etc. Knowledge from this course will be applied in the study of partial differential equations, variational calculus, special courses, and in writing coursework, qualification, and diploma theses.

Course objectives and goals

The purpose of the course is to provide future specialists with knowledge in the field of differential equations. The objectives include teaching students the basics and methods of differential equations theory, and applying these methods to solve the most important types of differential equations and systems of equations. The course helps students develop logical and algorithmic thinking necessary for solving theoretical and practical problems in the field; it also fosters skills in studying dynamic mathematical models of practical problems, their solutions, and analyzing the obtained results.

Format of classes

Lectures, practical classes, independent work, consultations. Final assessment – exam.

Competencies

GC06: Ability for abstract thinking, analysis, and synthesis.
PC01: Ability to use and adapt mathematical theories, methods, and techniques to prove mathematical statements and theorems.

Learning outcomes

LO02: Master the basic principles and methods of mathematical, complex, and functional analysis, linear algebra and number theory, analytical geometry, theory of differential equations, including partial differential equations, probability theory, mathematical statistics and random processes, numerical methods.
LO06: Master basic methods of developing discrete and continuous mathematical models of objects and processes, analytical study of these models for existence and uniqueness of their solutions.

Student workload

Total: 150 hours (5 ECTS credits): lectures – 32 hours, practical classes – 32 hours, independent work – 86 hours.

Course prerequisites

Students should have a fundamental knowledge of mathematical analysis, linear algebra, and analytical geometry.

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

Features of the course include individual homework assignments containing both standard and more complex tasks for advanced students. Students are encouraged to use computer programs for solving differential equations.

Program of the course

Topics of the lectures

Topic 1. First- and Second-Order Differential Equations Reducible in Order
1.1. Ordinary differential equations – basic concepts. Theorem on existence and uniqueness of the Cauchy problem solution. First-order differential equations. Direction fields. Equations with separable variables.
1.2. First-order homogeneous equations. Equations reducible to homogeneous. First-order linear equations.
1.3. Equations in total differentials. Integrating factor.
1.4. Second-order equations reducible in order. Examples.
1.5. Equations not solved for the derivative and their integration. Singular solutions of differential equations.

Topic 2. Higher-Order Linear Differential Equations and Systems of Linear Equations
2.1. Theorems on the structure and properties of solutions of linear homogeneous differential equations. Linear homogeneous differential equations with constant coefficients.
2.2. Theorem on the structure of solutions of linear nonhomogeneous differential equations. Method of variation of arbitrary constants and its use for finding a particular solution.
2.3. Linear nonhomogeneous differential equations with special right-hand sides. Finding solutions in the form of the right-hand side of the equation.
2.4. Linear differential equations with variable coefficients.
2.5. Systems of linear differential equations. Structure of solutions. Method of variable elimination.
2.6. Systems of linear homogeneous differential equations with constant coefficients. Using eigenvalue and eigenvector problems to find the solution.

2.7. Systems of linear nonhomogeneous differential equations. Theorem on the structure of solutions. Method of variation of variables and finding a particular solution.
2.8. Systems of linear nonhomogeneous differential equations with a special right-hand side.

Topic 3. Nonlinear Differential Equations and Introduction to the Theory of Motion Stability
3.1. Nonlinear differential equations. Method of successive approximations. Small parameter method.
3.2. Basic concepts of motion stability theory. Lyapunov stability definition. Variational equations. Lyapunov's theorems.
3.3. Singular points of systems of two linear homogeneous differential equations with constant coefficients.

Topics of the workshops

None.

Topics of the laboratory classes

Topic 1. First- and Second-Order Differential Equations Reducible in Order
1.1. First-order differential equations. Direction fields. Equations with separable variables.
1.2. First-order homogeneous equations. Equations reducible to homogeneous. First-order linear equations.
1.3. Equations in total differentials. Integrating factor.
1.4. Second-order equations reducible in order.
1.5. Equations not solved for the derivative and their integration. Singular solutions of differential equations.

Topic 2. Higher-Order Linear Differential Equations and Systems of Linear Equations
2.1. Linear homogeneous differential equations with constant coefficients.
2.2. Method of variation of arbitrary constants and its use for finding a particular solution.
2.3. Linear nonhomogeneous differential equations with special right-hand sides.
2.4. Linear differential equations with variable coefficients.
2.5. Systems of linear differential equations. Method of variable elimination.
2.6. Systems of linear homogeneous differential equations with constant coefficients. Using eigenvalue and eigenvector problems to find the solution.
2.7. Systems of linear nonhomogeneous differential equations. Method of variation of variables and finding a particular solution.
2.8. Systems of linear nonhomogeneous differential equations with a special right-hand side.

Topic 3. Nonlinear Differential Equations and Introduction to the Theory of Motion Stability
3.1. Nonlinear differential equations. Method of successive approximations.
3.2. Nonlinear differential equations. Small parameter method.
3.3. Singular points of systems of two linear homogeneous differential equations with constant coefficients.

Self-study

Independent work involves mastering the presented theoretical material, solving additional problems to consolidate the practical lessons, and completing individual assignments (IA) for each course section. Assignments are checked remotely, with scores awarded for each IA, contributing to the final grade. If necessary, students may be invited to revise or supplement their assignments.

IA 1. First- and second-order differential equations reducible in order.

IA 2. Higher-order linear differential equations and systems of linear equations.

IA 3. Nonlinear differential equations and introduction to the theory of motion stability.

Course materials and recommended reading

Main Literature
1. Higher Mathematics in Examples and Problems. Volume II. Differential and Integral Calculus of Multivariable Functions. Differential Equations and Series. Edited by Prof. Kurpa L.V. Kharkiv: NTU, 2009.
2. M.I. Shkil, V.M. Leyfura, P.V. Samusenko. Differential Equations. Kyiv: Tekhnika, 2003.
3. I.M. Kopas. Differential Equations: A Textbook for Engineering Specialties. Kyiv: Igor Sikorsky KPI, 2018. – 126 p.
4. A.M. Samoilenko, M.O. Perestyuk, A.O. Parasyuk. Differential Equations. Kyiv: Lybid, 2003. – 600 p.
5. T.P. Hoy, O.V. Makhnei. Differential Equations: Textbook. Ivano-Frankivsk: Simyk, 2012. – 352 p.

Additional Literature
1. L. Perko. Differential Equations and Dynamical Systems. Springer-Verlag, 1991. – 403 p.
2. Blanchard, P.; Devaney, R.L.; Hall, G.R. Differential Equations. Thompson, 2006.

Assessment and grading

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

Description of the Final Assessment Structure, Mandatory Assignments, and Scoring Procedure
Particular attention is paid to independent work and individual assignments.

Control tests – 20 points

Colloquia – 20 points

Individual assignments (IA) – 30 points

Final exam – 30 points.

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": show discipline, good manners, goodwill, honesty, responsibility. Conflict situations should be openly discussed in study groups with the teacher, and if it is impossible to resolve the conflict, they should be brought to the attention of the staff of the Institute's directorate.
Regulatory and legal support for the implementation of the principles of academic integrity of NTU "KhPI" is available on the website: http://blogs.kpi.kharkov.ua/v2/nv/akademichna-dobrochesnist/

Approval

Approved by	Date, signature	Head of the department Vyacheslav BURLAENKO
	Date, signature	Guarantor of the educational program Gennadiy LVOV