Syllabus
Course Program

Methods of Optimization

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
5

Language of instruction
English,

Lecturers and course developers

Yuriy Plaksiy
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Candidate of technical sciences, associate professor, professor of NTU "KhPI"

Author and co-author of more than 100 scientific and methodological publications. Courses: Computational Methods, Mathematical Foundations of Control Theory, Methods of Computational Experiment

More about the lecturer on the department's website

Viktor Fedorov
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Candidate of Technical Sciences, Associate Professor, Associate Professor of the Department of Mathematical Modeling and Intelligent Computing in Engineering Research interests: micromechanics of composite materials. Courses: Computational Methods, Mathematical Models of Nonlinear Media, Mechanics of Composite Materials, Mathematical Models of Composite Materials.

A complete list of publications and methodological materials is freely available on the website of the electronic repository of NTU "KhPI" : eNTUKhPIIR(ukr)

More about the lecturer on the department's website

General information

Summary

The course covers the following sections of optimization methods: methods for minimizing functions of one variable, methods for optimizing functions of many variables without constraints and under

constraints. The material is taught using the basic concepts of mathematical analysis, linear algebra and analytic geometry, programming skills (in the C++ environment or others).

Course objectives and goals

The purpose of studying the discipline " Methods of Optimization" is to form students' certain knowledge, skills and abilities, as well as the necessary competencies for the awareness and rational use of concepts and methods of optimization, as a subject of study, and as a means for studying other subject areas, in particular, automatic control systems, artificial intelligence systems, term papers and diploma papers. Learn how to effectively apply the theoretical apparatus and special optimization methods to solve applied problems of mathematical and computer sciences.

Format of classes

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

Competencies

PC 03. Ability to choose and apply mathematical methods to solve applied problems, modeling, analysis, design, management, forecasting, decision-making.
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 05. Be able to develop and use in practice algorithms related to the approximation of functional dependencies, numerical differentiation and integration, solving systems of algebraic, differential and integral equations, solving boundary value problems, finding optimal solutions.
LO 06. Possess 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.
LO 10. Possess methods of choosing rational methods and algorithms for solving mathematical optimization problems, operations research, optimal management and decision-making, data analysis.

Student workload

The total volume of discipline is 120 hours. (5 ECTS credits): lectures – 32 hours, laboratory work – 32 hours, individual work – 56 hours.

Course prerequisites

To successfully complete the course, students must possess:
– ability to make block diagrams of algorithms and program (programming);
–ability to differentiate and integrate (mathematical analysis);
– knowledge of numerical methods of analysis (methods of calculations).

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

The curriculum in the discipline "Optimization Methods" for students provides for participation in lectures and in the performance of individual laboratory work, independent study of theoretical and practical issues. 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 material using elements of distance learning;
• consolidation of theoretical material in laboratory classes.

Program of the course

Topics of the lectures

Topic 1. Introduction to the course "Optimization Methods".
Examples of formulation of optimization problems. Classification of optimization methods. The main tasks and assumptions of the course. Methods for minimizing the functions of one variable. Properties of functions of one variable. Methods for excluding intervals. Algorithm for finding the initial uncertainty interval.
Topic 2. One-dimensional optimization. Methods without using a derivative objective function..
Passive search, strategy, and algorithm. Sequential search methods. Dichotomy method. Half division method. Methods with a one-time function calculation. The golden ratio method. Fibonacci number method. Powell's Quadratic Approximation Method.
Topic 3. One-dimensional optimization. Methods using the derivative of the objective function.
Newton's method and its modifications: Newton's method with variable pitch (Newton-Raphson), secant method. Comparative characteristics of the methods.
Topic 4. Multi-Dimensional Optimization.
Classification of problems of optimization of functions of many variables. Fundamentals of Convex Programming. Kuhn-Tucker theorem. Necessary and Sufficient Conditions for the Extremum of Differentiable Functions in Problems without Constraints.
Topic 5. Unconditional Optimization Methods.
Gradient methods of the fastest descent and with step splitting. Gradient methods with different metrics (spherical, cubic, octahedral). Newton's method and its modifications. Methods of conjugate directions. Conjugate directions and their properties. Algorithm of the method of conjugate directions Hook-Jeeves method. Partan methods. Partan is the method of the fastest descent. Coordinate descent method: Powell's method of conjugate directions. Hook-Jeeves Method Deformed Polyhedron Method (Nelder-Mead). Methods of penalty functions. Gradient Projection Method.
Topic 6. Conditional Optimization Methods.
Gradient projection method. Danzig Method (Simplex Method).

Topics of the workshops

Not provided for in the curriculum.

Topics of the laboratory classes

Topic 1. Methods for Optimizing Functions of a Single Variable.
Properties of functions of one variable. Unimodal functions. Examples of optimization problems. Determination of the initial interval of localization of the minimum point. Swenn's algorithm (No. 1)
Topic 2. Methods without using a derivative objective function. Passive search method. Optimal strategy. Methods for excluding intervals:
Dichotomy method (No. 2). Method of half separation (No. 3). Methods with a one-time calculation of the objective function: Golden Ratio Method (No. 4). Fibonacci number method (No. 5). Comparison of methods for excluding intervals (No. 6). Polynomial Approximation and Point Estimation Methods: Powell's Method (No. 7).
Topic 3. Methods using the derivative of the objective function.
Newton's method (No. 8). Modifications of the Newtonian method: Newton-Raphson method with pitch adjustment (No. 9). The second and third modifications of Newton's method (No. 10).
Topic 4. Methods for Unconditional Optimization of Functions of Many Variables.
Gradient methods with spherical, cubic and octahedral metrics (No11, No12). Newton-Raphson method (l/r No. 13). The method of conjugate Fletcher-Reeves gradients (No. 14). Hook-Jeeves method (No. 15). Method of External Penalty Functions (No. 16).
Topic 5. Methods of Conditional Optimization of Functions of Many Variables.
Gradient projection method (Rosen method) (No. 17). Danzig Method (Simplex Method) (No. 18).

Self-study

The course involves individual laboratory work on one-dimensional and multivariate optimization methods with flowcharts, program text and a monitor screenshot confirming the performance of the

programs. The results of calculations and comparison of optimization methods with the corresponding conclusions are drawn up in an electronic report. Additional self-study materials are also recommended for students.

Course materials and recommended reading

Basic literature
1. Dyakon V.M., Kovalev L.E. Mathematical Programming: Tutorial / General edited by V.M. Mikhailenko. – 3rd edition, corrected and supplemented. – K.: Vid-vo Evrop. Univ., 2007. – 497 p..
2. Mathematical methods of operations research: textbook / E.A. Lavrov, L.P. Perhun, V.V. Shendrik and others. – Sumy: Sumy State University, 2017. – 212 p.
3. Movchan A.P. Textbook: Methods of Static Optimization. Study. Helps. / Movchan A.P., Stepanets O.V. — K.: NTUU "KPI", 2012. — 138 p.
4. Ukhanska O.M. Texts of lectures from the course "Optimization methods". – Lviv: NU "LP", 2003.
5. Vitlinsky, V.V., Nakonechnyi, S.I., Tereshchenko, T.O. Mathematical programming. – K: KNEU, 2001.
6. Plaksiy Yu.A., Tatarinova O.A. Feature optimization methods. Part 1. Methods for minimizing the functions of one variable. – Kharkiv, NTU "KhPI".-2016.
7. Methods of operations research. Helps. for students. specialty 122 "Computer Science" / KPI them. Igor Sikorsky; compiled by V. O. Kuzminykh, O. K. Molodid, R. A. Taranenko. – Electronic text data (1 file: 2,185 MB). – Kyiv : KPI them. Igor Sikorsky, 2020. – 117 p.

Additional literature.
1. Severyn V.P., Nikulina O.M. Methods and algorithms of multidimensional unconditional optimization: Textbook for students of computer specialties of all forms of education of higher education institutions / V.P. Severyn, O.M. Nikulina – Kharkiv: NTU "KhPI", 2023. – 160 p.
2. Shtelma O.M. Lecture notes from the course "Optimization methods and models" (for 2nd year full-time students of the educational level "bachelor" specialty 122 – Computer Science) / O.M. Shtelma; Kharkiv. National. Univ. of City. Hosp-va them. O. M. Beketova. – Kharkov: KhNUMG them. O. M. Beketova, 2018. – 38.
3. Plaksiy Y.A., Uspensky V.B. Methodical Instructions for the Laboratory and Practical Lesson "Study of Methods for Minimizing Functions of Many Variables" from the Course "Optimization Methods", Kharkiv, KSPU, 1999.

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 task (3 questions on theory + solution of 3 problems) and oral report.

Ongoing assessment: 2 online tests and labs (30% 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