МІНІСТЕРСТВО ОСВІТИ І НАУКИ УКРАЇНИ
ХАРКІВСЬКИЙ НАЦІОНАЛЬНИЙ ЕКОНОМІЧНИЙ УНІВЕРСИТЕТ ІМЕНІ СЕМЕНА КУЗНЕЦЯ

ЗАТВЕРДЖЕНО
на засіданні кафедри
інформаційних систем.
Протокол № 1 від 22.08.2023 р.

ПОГОДЖЕНО
Проректор з навчально-методичної роботи

_____ Каріна НЕМАШКАЛО

МЕТОДИ ВИРІШЕННЯ ІНЖЕНЕРНИХ ЗАДАЧ
робоча програма навчальної дисципліни (РПНД)

Галузь знань	**12 "Інформаційні технології"**
Спеціальність	**121 "Інженерія програмного забезпечення"**
Освітній рівень	**перший (бакалаврський)**
Освітня програма	**"Інженерія програмного забезпечення"**

Статус дисципліни	**вибіркова**
Мова викладання, навчання та оцінювання	**англійська**

Розробник:
к.ф.-м.н., доцент   підписано КЕП   Віктор ЗАДАЧИН

Завідувач кафедри
інформаційних систем   _____   Дмитро БОНДАРЕНКО

Гарант програми   _____   Олег ФРОЛОВ

**Харків
2024**

MINISTRY OF EDUCATION AND SCIENCE OF UKRAINE
SIMON KUZNETS KHARKIV NATIONAL UNIVERSITY OF ECONOMICS

APPROVED
at the meeting of the department
information systems
Protocol № 1 of 22.08.2023

AGREED
Vice-rector for educational and methodical work

Karina NEMASHKALO

METHODS OF SOLVING ENGINEERING PROBLEMS

Program of the course

Field of knowledge   **12 "Information technology"**
Specialty   **121 "Software engineering"**
Study cycle   **first (bachelor)**
Study programme   **"Software Engineering"**

Course status   **Elective**
Language   **English**

Developers:
Ph.D. (Mathematical
sciences),
associate professor   digital signature   Viktor ZADACHYN
Head of Information Systems
Department:
Ph.D. (Technical sciences),   Dmytro BONDARENKO
associate professor

Head of Study Programme:
Ph.D. (Technical sciences),   Oleg FROLOV
associate professor

Kharkiv
2024

INTRODUCTION

The modern development of science and computer technology is characterized by an ever-increasing level of use of computer models both for studying the behavior of phenomena and processes surrounding a person and for solving practical problems related to management and forecasting.

Studying the course "Methods of solving engineering problems" involves acquiring theoretical knowledge and mastering practical skills regarding the basic methods of solving engineering problems that arise during software development; and mastering the methods of calculations on modern computers using packages of special application programs.

Education seekers are in the process of learning to acquire the necessary knowledge during classroom classes: lecture and laboratory. Self-studies is also of great importance in the process of studying and consolidating knowledge among education seekers.

The purpose of teaching this course is the formation of theoretical knowledge on the basics of numerical analysis and operations research, assimilation of education seeker's basic numerical methods, and acquiring skills in their application to solve mathematical problems that arise during software development. At the same time, much attention is paid to practical work education seekers on personal computers using mathematical packages.

The object of study of the course is typical mathematical problems, which are reduced to the solution of problems that arise during the development of information systems and modeling systems.

The subject of studying the course is the well-known numerical methods of solving mathematical problems and optimization methods.

The Learning outcomes and competence formed by the course are defined in the table. 1.

Table 1

Learning outcomes and competencies formed by the course

Learning outcomes	Competences
LO01	GC01, GC02, GC05, GC06, SC08
LO05	GC01, GC02, SC07, SC08, SC14

where LO01. Analyze, purposefully search for and select the information and reference resources and knowledge necessary for solving professional tasks, taking into account modern achievements of science and technology.

LO05. Know and apply relevant mathematical concepts, methods of domain, system, and object-oriented analysis, and mathematical modeling for software development.

GC01. Ability to abstract thinking, analysis, and synthesis.

GC02. Ability to apply knowledge in practical situations.

GC05. Ability to learn and master modern knowledge.

GC06. Ability to search, process, and analyze information from various sources.

SC07. Knowledge of data information models, and ability to create software for data storage, extraction and processing.

SC08. Ability to apply fundamental and interdisciplinary knowledge to successfully solve software engineering tasks.

SC14. Ability to algorithmic and logical thinking.

COURSE CONTENT

Content module 1. Numerical methods

Topic 1. Introduction. The subject of the course, its content and tasks

1.1. Introduction. The subject of the course, its content, and tasks.

Topic 2. The essence of numerical methods. General concepts.

2.1. The essence of numerical methods. General concepts.

2.2. Characteristics of numerical methods. Decision error.

2.3. Arithmetic with floating point. Rounding error when calculating on a floating-point computer.

Topic 3. Solving systems of linear algebraic equations

3.1. Formulation of the problem. Direct and Iterative methods, and their difference.

3.2. Direct methods of solving systems of algebraic linear equations. Gauss exclusion method. Gauss method with selection of the main element.

3.3. Iterative methods of solving systems of algebraic linear equations. The simple iteration method, and its convergence conditions. Seidel's method.

3.4. Solving systems of linear algebraic equations of large dimensions. Types of sparse matrices. Methods of solving systems of linear equations of large dimensions with sparse matrices.

Topic 4. Numerical methods of solving nonlinear equations

4.1. Numerical methods of solving nonlinear equations with one unknown. Formulation of the problem. Dichotomy method.

4.2. Numerical methods of solving systems of nonlinear equations. Formulation of the problem. Newton's method and simple iteration method. The method of least squares.

Topic 5. Numerical methods of approximation of functions. Approximation, interpolation, and extrapolation

5.1. Setting problems of approximation of functions and their difference.

5.2. Approximation of functions. The method of least squares for approximation of functions.

5.3. Interpolation of functions. Interpolation is linear and quadratic. Lagrange interpolation polynomial. Newton's interpolating polynomial. Spline interpolation.

Topic 6. Numerical differentiation of functions

6.1. Formulation of the problem. Formulas of numerical differentiation of functions.

Topic 7. Numerical integration of functions

7.1. Formulation of the problem. Formula of trapezoids. Simpson's formula.

Topic 8. Numerical integration of ordinary differential equations. Cauchy's problem

8.1. Formulation of Cauchy's problem. Formulation of the Cauchy problem for the differential equation of the nth order and the system of differential equations.

8.2. One-step methods of solving the Cauchy problem. Euler's method, Runge-Kutt methods, their comparison.

8.3. Multistep methods of solving the Cauchy problem. The Adams–Bashforth method, the forecast and correction method, and their comparison.

8.4. Implicit methods of solving hard problems. The concept of a hard Cauchy problem. Implicit methods of Euler and Runge–Kutt.

Topic 9. Boundary value problems for ordinary differential equations

9.1. Formulation of the boundary value problem. Problem formulation for ordinary differential equations.

9.2. Numerical methods of solving the boundary value problem for ordinary differential equations. Finite difference method.

Topic 10. Methods of mathematical physics.

10.1. Formulation of mathematical physics problems. Dirichlet's problem, Neumann's problem.

10.2. Numerical methods of solving mathematical physics problems. Finite difference method. Finite element method.

Content module 2. Optimization methods

Topic 11. Formulation and classification of optimization problems, general concepts

11.1. General formulation of the optimization problem, general concepts. Concept of the objective function and admissible set.

11.2. Classification of optimization problems. Mathematical programming. Unconditional and conditional optimization. Linear and non-linear programming.

Topic 12. Numerical methods of finding the extremum of functions of one variable

12.1. Formulation of the problems search extremum of functions of one variable.

12.2. Numerical methods for looking for an extremum of a function of one variable. Dichotomy method. Golden ratio method.

Topic 13. Unconditional optimization methods

13.1. Statement of the problem of unconditional optimization.Necessary conditions for the minimum of the 1st and 2nd orders of a function of several variables. General scheme of numerical methods for solving the problem of unconditional optimization.

13.2. Numerical methods of unconditional optimization. Gradient methods. Method of conjugate gradients. Newton's method. Quasi-Newtonian methods. Methods of random search.

Topic 14. Methods of non-linear programming

14.1. Formulation of the nonlinear programming problem Minimum conditions are required.

14.2. Numerical methods of nonlinear programming. Penalty function method. The modified Lagrange function method.

Topic 15. Methods of linear programming

15.1. Formulation of the linear programming problem. Pstatements of applied problems, which are reduced to a problem linear programming.

15.2. Numerical methods of linear programming. Simplex method.

The list of laboratory studies and hours of self-study is given in the technological card of the course is given in Table 2.

Table 2

List of laboratory studies

Topic name	Content
Topic 3.	Numerical methods of solving systems of linear algebraic equations. Gauss exclusion method. Method of iterations
Topic 4.	Numerical methods of solving equations and systems of nonlinear equations. Newton's method, and simple iteration method. The method of least squares
Topic 5.	Numerical methods of approximation of functions. Approximation of functions. Interpolation of functions
Topic 8.	Numerical methods of solving the Cauchy problem for ordinary differential equations. Euler, Runge-Kut methods. Multi-step methods
Topic 9.	Numerical methods of solving the boundary value problem for ordinary differential equations. Finite difference method
Topics 12, 13.	Numerical methods for finding the extremum of functions of one variable. Golden ratio method. Unconditional optimization methods. Gradient methods. Method of conjugate gradients. Newton's method
Topic 14.	Methods of non-linear programming. Penalty function method. The modified Lagrange function method
Topic 15.	Solving linear programming problems

The list of self-studies in the course is given in Table 3.

Table 3

List of self-studies

Topic name	Content
Topic 2 – 15	Studying lecture material
Topic 3 –5, 8, 9, 12-15	Preparation for laboratory classes
Topic 2 – 15	Preparation for the exam

The number of hours of lecture and laboratory studies and hours of self-study is given in the technological card of the course.

TEACHING METHODS

In the process of teaching the course, in order to acquire certain learning outcomes, to activate the educational process, it is envisaged to use such teaching methods as:

Verbal (lecture (Topic 1, 2, 5, 6, 7, 9, 10, 15), problem lecture (Topic 3, 8), visualization lecture (Topic 13)).

In-person (demonstration (Topic 2-15)).

Laboratory work (Topic 3, 4, 5, 8, 9, 12, 13, 14, 15), case method (Topic 10, 15).

FORMS AND METHODS OF ASSESSMENT

The University uses a 100-point cumulative system for assessing the learning outcomes of students.

Current control is carried out during lectures and laboratory classes and is aimed at checking the level of preparedness of the student to perform specific work and is evaluated by the sum of points scored:

− for courses with a form of semester control exam: the maximum amount is 60 points; the minimum amount that allows a student of higher education to pass an exam is 35 points.

Final control includes semester control and certification of the student of higher education.

Semester control is conducted in the form of an exam. The exam is taken during the exam session.

The maximum number of points that a student of higher education can receive during the exam is 40 points. The minimum amount for which the exam is considered passed is 25 points.

The final grade in the course is determined by summing all points received during the current control and the exam grade.

During the teaching of the course, the following control measures are used:

Current control: defense of laboratory works (40 points), written control works (20 points).

Semester control: Exam (40 points).

More detailed information on the assessment system is provided in the technological card of the course.

An example of an exam card and assessment criteria.

Semyon Kuznets Kharkiv National University of Economics
First (bachelor) level of higher education
Specialty "Software Engineering"

Educational and professional program "Software Engineering"
Semester V
The course "Methods of solving engineering problems»

EXAM CARD

Task 1.
Solve the system of equations numerically $\{sin\ sin\ x_1\ =\ -2x_2 + 2\ \ cos\ cos\ x_1\ =\ -x_2 + 1.5$
$(x^0 = (0;\ 0))$

Formulate a mathematical problem in a general form and list the numerical methods of solving it.

Task 2.
The dependence (HQ characteristic of the pump) of the head created by the pump (H) on the water flow rate (Q) is described by the function $H = HF - SFQ\beta$ (HF, SF, β – dependence parameters). As a result of field experiments, the following data were obtained:

Q, m3/h	5	20	30	35
H, m of water Art.	209	194	165	142

Estimate the value of the pressure that will be created by the pump at a water consumption of Q=32 m3/h. Build a dependency graph.

Task 3.

The enterprise produces combined feed for animals, produced from 3 types of grain crops: corn, wheat and barley. Estimate what the mixture should be so that the feed price is minimal, the caloric content of 100 grams of feed is at least 353 kcal and the protein content is at least 22.1%, if the following data are known:

The name of the culture	Price for 1 kg, UAH...	Calorie content of 100 grams, kcal	Protein content, %
Corn	5.1	300	21
Wheat	5.4	400	23
Barley	5.25	360	22

"___"_____20___yr.

Examiner | PhD, Associate Professor Zadachynn V.

Chief Department | PhD, Associate Professor Bondarenko D.

Assessment criteria

The exam card consists of three tasks: the first - stereotypical, the second and third - heuristic. The final grade for the exam is the sum of the marks for each task (maximum 40 points). Each task is evaluated according to the following scale.
For task 1(maximum 10 points).

10 points	The task is completed in full. The results were checked for correctness. Correct answers are received, there is an explanation for completing the task, and conclusions are drawn. Formulated mathematical formulation of the problem.
8 points	The task is completed in full. The results were checked for correctness. Correct answers were received, but explanations for the task and conclusions were not given. Formulated mathematical formulation of the problem.

7 points	The task has been completed, the results have been obtained, but not checked for correctness, and no explanations have been given for the completion of the task and conclusions. Formulated mathematical formulation of the problem.
5 points	The task has not been completed completely, the results have not been obtained, no explanations have been given for the completion of the task and conclusions.
4 points	Task not completed. There is a written program, but it does not work.
2 points	Task not completed. There is a fragment of the written program.
0 points	Task not completed.

For task 2(maximum 15 points).

15 points	The task is completed in full. The results were checked for correctness. Correct answers are received, there is an explanation for completing the task, and conclusions are drawn. Formulated mathematical model.
13 Points	The task is completed in full. The results were checked for correctness. Correct answers were received, but explanations for the task and conclusions were not given. Formulated mathematical model.
12 points	The task has been completed, the results have been obtained, but not checked for correctness, and no explanations have been given for the completion of the task and conclusions. Formulated mathematical model.
10 points	The task has not been completed completely, the results have not been obtained, and no explanations have been given for the completion of the task and conclusions. Formulated mathematical model.
4 points	Task not completed. The mathematical model is not formulated. There is a written program, but it does not work.
2 points	Task not completed. The mathematical model is not formulated. There is a fragment of the written program.
0 points	Task not completed.

For task 3(maximum 15 points).

15 points	The task is completed in full. The results were checked for correctness. Correct answers are received, there is an explanation for completing the task, and conclusions are drawn. Formulated mathematical model.
13 Points	The task is completed in full. The results were checked for correctness. Correct answers were received, but explanations for the task and conclusions were not given. Formulated mathematical model.
12 points	The task has been completed, the results have been obtained, but not checked for correctness, and no explanations have been given for the completion of the task and conclusions. Formulated mathematical model.
10 points	The task has not been completed completely, the results have not been obtained, and no explanations have been given for the completion of the task and conclusions. Formulated mathematical model.
4 points	Task not completed. The mathematical model is not formulated. There is a written program, but it does not work.
2 points	Task not completed. The mathematical model is not formulated. There is a fragment of the written program.
0 points	Task not completed.

RECOMMENDED LITERATURE

Main

1. Zadachyn V.M., Konyushenko I.H. Educational manual "Numerical methods" - Kharkiv: Ed. HNEU named after S. Kuznetsa, 2014. – 190 p. http://www.repository.hneu.edu.ua/jspui/handle/123456789/8310

2. Zadachyn V.M. System modeling and optimization methods: methodological recommendations for laboratory work for students of the field of knowledge 12 "Information technologies" of the first (bachelor's) level: [Electronic edition] - Kharkiv: Ed. HNEU named after S. Kuznetsa, 2019. – 210 p.http://repository.hneu.edu.ua/handle/123456789/22458

3. Goncharov O. A. Numerical methods of solving applied problems: teaching. manual / O. A. Goncharov, L. V. Vasylieva, A. M. Yunda. – Sumy: Sumy State University, 2020. – 142 p.

4. Methods of optimization and operations research: a study guide / Compilers: Y. B. Sikora, A.Y. Shchehorskyi, B.L. Yakymchuk – Zhytomyr: Department of ZhDU named after Ivan Franko, 2019. - 148 p.

Additional

5. Chasnov JR Numerical Methods for Engineer: Lecture Notes for Coursera – The Hong Kong University Science and Technology, 2020. - 217 p.

6. Michael VK, Jingzhi L. Partial Differential Equations: Theory, Numerical Methods and Ill-Posed Problems - Nova Publishing, 2022. - 347 p.

7. Methods of optimization and operations research: training manual / O. O. Yemets. - Poltava: PUET, 2019. - Part 1. - 245 p.

8. Methods of optimization and operations research: training manual / O. O. Yemets. - Poltava: PUET, 2019. - Part 2. - 139 p.

Information resources

9. Introduction to Mathematical Optimization: with Python– https://indrag49.github.io/Numerical-Optimization/

10. Collaborative –https://colab.research.google.com/

11. Numerical Programming with Python – https://python-course.eu/numerical-programming/

12. Statistics with R –http://zoonek2.free.fr/UNIX/48_R/all.html

13. The Comprehensive R Archive Network –http://cran.r-project.org

14. The site of personal educational systems of Khnei National University named after S. Kuznetsia - https://pns.hneu.edu.ua/course/view.php?id=9021