Національний технічний університет України
«КИЇВСЬКИЙ ПОЛІТЕХНІЧНИЙ ІНСТИТУТ
імені ІГОРЯ СІКОРСЬКОГО»

**Кафедра технології неорганічних речовин, водоочищення та загальної хімічної технології**

# Optimization

# of chemical engineering processes and systems

## Syllabus

| Details of the discipline | |
|---|---|
| **Level of higher education** | ***second (master's)*** |
| **Branch of knowledge** | *16 Chemical Engineering and Bioengineering* |
| **Specialty** | *161 Chemical technology and engineering* |
| **Educational program** | *For all educational programs of specialty 161 Chemical Technology and Engineering* |
| **Discipline status** | *General training* |
| **Form of study** | *Blended* |
| **Year of preparation, semester** | *1st year, spring semester* |
| **The scope of discipline** | *4 credits* |
| **Semester control / control measures** | *Written pass-fail exam* |
| **Timetable** | *Lectures: 2 academic hours a week for two weeks, computer classes 2 academic hours a week according to the schedule on rozklad.kpi.ua* |
| **Language of instruction** | *English / Ukrainian* |
| **Information about the leading teacher of the course / teachers** | Lecturer:<br>*Arcady Shakhnovsky, Ph.D., Associate Professor, AMShakhn@xtf.kpi.ua*<br>Practical classes:<br>*Arcady Shakhnovsky, Ph.D., Associate Professor, AMShakhn@xtf.kpi.ua* |
| **Course placement** | Google Classroom (Google G Suite for Education, Sikorsky-distance platform); access at the invitation of the teacher |

## Curriculum of the discipline

### 1. Description and purpose of the discipline, subject of study and learning outcomes

*Mathematical optimization methods and optimization software are an important tool for solving applied and fundamental problems in chemical engineering and related fields (both on a laboratory and industrial scale). The use of optimization models makes it possible to develop proposals for improving the research process while sharply reducing the required amount of experiments on the object of study.*

***The subject of the discipline**: the course will study common methods of formulating applied professional problems in the form of mathematical optimization problems, methods and software for solving such problems, as well as some innovative approaches to optimization of processes and systems (game theory, neural networks)..*

***The purpose** of the discipline is to form students' abilities:*

- *- using mathematical methods of optimization to solve typical problems of chemistry and chemical engineering;*
- *- applying modern software to perform calculations on the optimization of chemical technology*

*After mastering the discipline, students must demonstrate the following learning outcomes:*

***knowledge:***

- *capabilities of computer in solving computational problems of chemical technologies and water treatment;*
- *methods of presenting scientific information; namely the selection of the object of study, the subject of research, scientific novelty, justification of the purpose and setting goals;*
- *methods of modeling and optimization.*

***skills:***

- *communicate clearly and unambiguously professional knowledge, own justifications and conclusions to specialists and the general public;*
- *develop an algorithm for solving the optimization problem based on the chosen method of optimization in accordance with the type of problem, analyze the results.*

***experience:***

- *use of mathematical optimization methods to solve typical problems of chemistry and chemical technology;*
- *application of standard software to perform calculations on the optimization of chemical technology facilities.*

## 2. Prerequisites and postrequisites of the discipline (place in the structural and logical scheme of education according to the relevant educational program)

*The list of disciplines, knowledge and skills that the student needs to successfully master the discipline:*

| | |
|---|---|
| *Higher mathematics* | *Properties of continuous functions. Systems of algebraic equations. Ordinary differential equations and their systems. Matrices and matrix transformations.* |
| *Information Technology* | *Principles of information processing in mathematical packages and general purpose software packages - MS Excel. Fundamentals of algorithmization. Working with modern software products: VBA / Mathcad* |
| *Numerical methods in chemistry and chemical technology* | *Numerical methods for solving algebraic and differential equations, methods of numerical integration, approximation of functions used to solve typical engineering problems of chemistry and chemical technology, and computer tools for their implementation. Fundamentals of applied statistics.* |

*Use of learning outcomes: to perform a master's thesis, in further professional activities.*

## 3. The content of the discipline

*Topic 1. General characteristics of optimization methods*

*Statement of the optimization problem. The concept of optimization. Qualitative formulation of the optimization problem. Some typical problems that are reduced to optimization problems: the optimal thickness of thermal insulation, the optimal choice of raw materials and distribution of production capacity, the optimal composition of the mixture, the optimal operating conditions of the equipment. Hierarchy of optimization problems on the example of chemical industry objects.*

*Mathematical formulation is an optimization problem. Target function, limitations. Geometric interpretation of the objective function and constraints.*

*Principles of construction and types of objective function (on the example of optimization of chemical industry facilities).*

*Mathematical models of processes and their role in solving optimization problems. Classification of mathematical models for optimization needs. Degrees of freedom of the model.*

*Classes of optimization problems. Linear programming. Nonlinear programming. Discrete programming. Dynamic programming. Geometric programming. Variational calculus. The principle of maximum. Stochastic programming problems.*

*General procedure for solving optimization problems. Classification of methods for solving optimization problems. Obstacles to the application of mathematical methods of optimization and their overcoming.*

*The most common programs for solving optimization problems.*

*Application of classical analysis methods to solve multidimensional optimization problems.*

*Topic 2. Linear programming (LP)*

*General view of the linear programming problem (LLP). Basic definitions. Typical problems of LP. Standard form of ZLP. Geometric interpretation of ZLP on the example of a problem with two variables. Simplex method of solving LP problems. The general idea of the simplex method. The concept of reference plan. Relationship between reference plans and vertices of an admissible polyhedron Theoretical foundations of the simplex method: the criterion of optimality, the sign of the unsolvability of the ZLP, the rules of transition to the next reference plan. Simplex method algorithm. Simplex table.*

*Duality in linear programming. A pair of dual LP problems. Rules for constructing dual problems. Duality theorems. Economic interpretation of a pair of dual problems. Theoretical foundations of the dual simplex method: the criterion of optimality, the sign of the insolubility of the evil, the rules of transition to the next pseudo-plan. Algorithm of the method.*

*Analysis of the sensitivity of the solution of the linear programming problem to changes in the input data. Changes in the conditions of the problem that affect the admissibility of the solution. Changes to the right parts of the restrictions. Changes in the conditions of the problem that affect the optimality of the solution.*

*Transport problem and methods of its solution. Statement of a transport problem (TOR) and its mathematical model. Vehicle modifications. Necessary and sufficient condition for solving the vehicle. Methods for determining the initial reference plan of the vehicle: the method of the north-west corner, the method of the minimum element. Criterion of optimality of the reference plan of the vehicle. Potential method. Appointment task. Hungarian method of solving the assignment problem.*

*Limits of application of LP problems in solving applied problems in chemical technology, chemical engineering, biotechnology. Optimal choice of raw materials and distribution of production capacity*

*Topic 3 Nonlinear programming. Solving optimization problems in the absence of constraints*

*Statement and properties of nonlinear programming problems. One-dimensional optimization. Methods of excluding intervals: half division, "golden" section, Fibonacci numbers. Use of polynomial approximation: Powell's method. Methods using derivatives.*

*Direct search methods for functions of many variables. Scanning method, its properties and application. Hook-Jeeves method. Simplex method and its properties. Nelder-Mead method.*

*Gradient optimization methods: first and second order Newton methods; relaxation method and the fastest descent method.*

*Global and local optimums. Optimal sensitivity.*

*Statistical methods for finding the optimum. The problem of global optimum in solving optimization problems. Statistical approach to finding the optimum: "the simplest statistical search". Modern statistical methods of finding the optimum: classification, features of computer implementation.*

*Genetic algorithms. The concept of the algorithm "simulated hardening", the Luus-Jaacal method, the method of "ant colony".*

*Topic 4 Nonlinear programming. Optimization methods for constrained problems*

*Lagrange multiplier method. Method of penalty functions. Modifications of unlimited optimization methods for solving constrained problems. Comprehensive method.*

*Topic 5. Nonlinear programming. Decision making based on the results of nonlinear optimization.*

*Use of nonlinear programming methods in chemical technology, chemical engineering, biotechnology. Selection of optimal modes of operation of technological processes and systems. Optimal choice of mode and design parameters. Optimization and sensitivity analysis of reaction processes.*

*Topic 6. Discrete programming*

*The subject of discrete programming. Varieties of discrete programming problems. The general idea of cutting methods.*

*Solving linear integer problems by the Gomori method. Data representation in the form of a network and a tree. Probabilistic methods for solving discrete programming problems. The method of branches and boundaries.*

*Limits of application of discrete programming problems in solving applied problems in chemical technology, chemical engineering, biotechnology. Synthesis of HTS structure: the concept of the method of structural parameters.*

*Topic 7. Optimal control of technological systems and dynamic optimization*

*Variational calculus in optimal control: the problem of final state control, the problem of optimal control with a generalized quality indicator.*

*General idea of dynamic programming. Application of dynamic programming in solving optimal control problems. Optimal control of nonlinear systems. Optimal control of systems with distributed parameters.*

*Bellman's optimality principle. Recurrent ratios. Solution of the problem of optimal distribution of reaction volumes in the cascade of reactors of ideal mixing.*

*Topic 8. Solving multi-purpose optimization problems*

*Problem statement with many optimization criteria. Multicriteria task of production optimization. Finding a compromise solution. Many Pareto solutions. Procedures for solving multicriteria problems. Reduction of a multicriteria problem to a single-criteria one. Use of convolutions of different types. Desirability functions and their use in many optimization criteria.*

*Topic 9. Special problems that come down to solving optimization problems.*

*Uncertainty optimization, stochastic programming. The role of the probabilistic component in modeling and optimization of chemical-technological processes. Monte Carlo method. Stochastic programming.*

*Conflict problems optimization. Fundamentals of game theory.*

*Basic concepts of artificial neural networks. Biological neuron and its mathematical model. Artificial neuron: combined input and activation function. Single-layer artificial neural networks. Multilayer artificial neural networks. Learning artificial neural networks. Studying with a teacher. Learning without a teacher. Perceptron. Perceptron training. Modern neural network and library. Application of artificial neural networks.*

## 4. Training materials and resources

*The teaching materials listed below are available in the university library and in the library of the Department of Inorganic Substances Technology, Water Treatment and General Chemical Technology. Basic literature is required for study, other materials are optional. Sections and topics that the student should get acquainted with on their own, the teacher notes in lectures and practical classes.*

***Base:***


1. *Edgar T. F., Himmelblau D. M., Lasdon L. S. Optimization of chemical processes. McGraw Hill, New York, 2001, 672 pp. URL: http://sharif.ir/~pishvaie/Articles/OptimizationArticles/Semester_9293_2/SomeUsefulRefs/Optimization%20of%20Chemical%20Processes%20by%20David.%20M.%20Himmelblau%20(Author).pdf*
2. *Diwekar U. Introduction to Applied Optimization. Springer, 2008. - 292 pp. URL: https://www.academia.edu/6907208/Diwekar_Introduction_to_Applied_Optimization*
3. *Taha Hamdy A. Operations Research: An Introduction. Upper Saddle River, N.J. : Pearson/Prentice Hall Eighth edition. 2007. 813 pp.*


***Optional:***


4. *Sieniutycz S., Jezowski J. Energy Optimization in Process Systems and Fuel Cells. 3rd Edition. Elsevier, 2018. 788 pp.*
5. *Practical Optimization - Algorithms and Engineering Applns / A. Antoniou, W. Lu. Springer. 2007. 670 pp.*
6. *Baldick R. Applied optimization. Formulation and Algorithms for Engineering Systems. Cambridge University Press. 2009. 792 pp.*
7. *Mathematical Modeling Approaches for Optimization of Chemical Processes / Gabriela Corsano, Jorge M. Montagna, Oscar A. Iribarren and Pío A. Aguirre. Nova Science Publishers. 2009. 103 pp.*

***Information resources***

8. *Distance course Google G Suite for Education. Access mode: Google Classroom (Google G Suite for Education, domain LLL.kpi.ua, Sikorsky-distance platform); the course code is provided by the teacher.*

## Educational content

### 5. Methods of mastering the discipline / educational component

*Lectures*

*Lectures on the discipline are held in parallel with the students' work on a computer workshop and their consideration of issues submitted for independent work. When giving lectures in blended learning, video conferencing tools (Google Meet, Zoom, etc.) and illustrative material in the form of presentations are used, which are posted on the Sikorsky-distance platform [9]. After each lecture it is recommended to get acquainted with the materials recommended for independent study, and before the next lecture - to repeat the material of the previous one.*

| № | Description |
|---|---|
| 1 | *Topic 1. General characteristics of optimization methods*<br><br>*Statement of the optimization problem. The concept of optimization. Qualitative formulation of the optimization problem. Some typical problems that are reduced to optimization problems: the optimal thickness of thermal insulation, the optimal choice of raw materials and distribution of production capacity, the optimal composition of the mixture, the optimal operating conditions of the equipment. Hierarchy of optimization problems on the example of chemical industry objects.*<br><br>*Mathematical formulation is an optimization problem. Target function, limitations. Geometric interpretation of the objective function and constraints.*<br><br>*Principles of construction and types of objective function (on the example of optimization of chemical industry facilities).*<br><br>*Mathematical models of processes and their role in solving optimization problems. Classification of mathematical models for optimization needs. Degrees of freedom of the model.*<br><br>*Classes of optimization problems. Linear programming. Nonlinear programming. Discrete programming. Dynamic programming. Geometric programming. Variational calculus. The principle of maximum. Stochastic programming problems.*<br><br>*General procedure for solving optimization problems. Classification of methods for solving optimization problems. Obstacles to the application of mathematical methods of optimization and their overcoming.*<br><br>*The most common programs for solving optimization problems.*<br><br>*Application of classical analysis methods to solve multidimensional optimization problems.* |
| 2 | *Topic 2. Linear programming (LP)*<br><br>*General view of the linear programming problem (LLP). Basic definitions. Typical problems of LP. Standard form of ZLP. Geometric interpretation of ZLP on the example of a problem with two variables. Simplex method of solving LP problems. The general idea of the simplex method. The concept of reference plan. Relationship between reference plans and vertices of an admissible polyhedron Theoretical foundations of the simplex method: the criterion of optimality, the sign of the unsolvability of the ZLP, the rules of transition to the next reference plan. Simplex method algorithm. Simplex table.*<br><br>*Duality in linear programming. A pair of dual LP problems. Rules for constructing dual problems.* |

| | |
|---|---|
| | *Duality theorems. Economic interpretation of a pair of dual problems. Theoretical foundations of the dual simplex method: the criterion of optimality, the sign of the insolubility of the evil, the rules of transition to the next pseudo-plan. Algorithm of the method.*<br><br>*Analysis of the sensitivity of the solution of the linear programming problem to changes in the input data. Changes in the conditions of the problem that affect the admissibility of the solution. Changes to the right parts of the restrictions. Changes in the conditions of the problem that affect the optimality of the solution.*<br><br>*Transport problem and methods of its solution. Statement of a transport problem (TOR) and its mathematical model. Vehicle modifications. Necessary and sufficient condition for solving the vehicle. Methods for determining the initial reference plan of the vehicle: the method of the north-west corner, the method of the minimum element. Criterion of optimality of the reference plan of the vehicle. Potential method. Appointment task. Hungarian method of solving the assignment problem.*<br><br>*Limits of application of LP problems in solving applied problems in chemical technology, chemical engineering, biotechnology. Optimal choice of raw materials and distribution of production capacity* |
| *3* | *Topic 3 Nonlinear programming. Solving optimization problems in the absence of constraints*<br><br>*Statement and properties of nonlinear programming problems. One-dimensional optimization. Methods of excluding intervals: half division, "golden" section, Fibonacci numbers. Use of polynomial approximation: Powell's method. Methods using derivatives.*<br><br>*Direct search methods for functions of many variables. Scanning method, its properties and application. Hook-Jeeves method. Simplex method and its properties. Nelder-Mead method.*<br><br>*Gradient optimization methods: first and second order Newton methods; relaxation method and the fastest descent method.*<br><br>*Global and local optimums. Optimal sensitivity.*<br><br>*Statistical methods for finding the optimum. The problem of global optimum in solving optimization problems. Statistical approach to finding the optimum: "the simplest statistical search". Modern statistical methods of finding the optimum: classification, features of computer implementation.*<br><br>*Genetic algorithms. The concept of the algorithm "simulated hardening", the Luus-Jaacal method, the method of "ant colony".* |
| *4* | *Topic 4 Nonlinear programming. Optimization methods for constrained problems*<br><br>*Lagrange multiplier method. Method of penalty functions. Modifications of unlimited optimization methods for solving constrained problems. Comprehensive method.* |
| *5* | *Topic 5. Nonlinear programming. Decision making based on the results of nonlinear optimization.*<br><br>*Use of nonlinear programming methods in chemical technology, chemical engineering, biotechnology. Selection of optimal modes of operation of technological processes and systems. Optimal choice of mode and design parameters. Optimization and sensitivity analysis of reaction processes.* |
| *6* | *Topic 6. Discrete programming*<br><br>*The subject of discrete programming. Varieties of discrete programming problems. The general idea of cutting methods.*<br><br>*Solving linear integer problems by the Gomori method. Data representation in the form of a network and a tree. Probabilistic methods for solving discrete programming problems. The method of branches and boundaries.*<br><br>*Limits of application of discrete programming problems in solving applied problems in chemical technology, chemical engineering, biotechnology. Synthesis of HTS structure: the concept of the* |

| | |
|---|---|
| | *method of structural parameters.* |
| *7* | *Topic 7. Optimal control of technological systems and dynamic optimization*<br>*Variational calculus in optimal control: the problem of final state control, the problem of optimal control with a generalized quality indicator.*<br>*General idea of dynamic programming. Application of dynamic programming in solving optimal control problems. Optimal control of nonlinear systems. Optimal control of systems with distributed parameters.*<br>*Bellman's optimality principle. Recurrent ratios. Solution of the problem of optimal distribution of reaction volumes in the cascade of reactors of ideal mixing.* |
| *8* | *Topic 8. Solving multi-purpose optimization problems*<br>*Problem statement with many optimization criteria. Multicriteria task of production optimization. Finding a compromise solution. Many Pareto solutions. Procedures for solving multicriteria problems. Reduction of a multicriteria problem to a single-criteria one. Use of convolutions of different types. Desirability functions and their use in many optimization criteria.* |
| *9* | *Topic 9. Special problems that come down to solving optimization problems.*<br>*Uncertainty optimization, stochastic programming. The role of the probabilistic component in modeling and optimization of chemical-technological processes. Monte Carlo method. Stochastic programming.*<br>*Conflict problems optimization. Fundamentals of game theory.*<br>*Basic concepts of artificial neural networks. Biological neuron and its mathematical model. Artificial neuron: combined input and activation function. Single-layer artificial neural networks. Multilayer artificial neural networks. Learning artificial neural networks. Studying with a teacher. Learning without a teacher. Perceptron. Perceptron training. Modern neural network and library. Application of artificial neural networks.* |

*Computer practical classes*

*The purpose of the computer practice is to consolidate the theoretical knowledge gained during the study of the discipline. The computer practical classes is aimed at consolidating the theoretical provisions of the discipline and the acquisition by students of skills and experience of their practical application under the guidance of a teacher by performing appropriately formulated tasks.*

| ***Week*** | ***Topic*** | ***Description of the planned work*** |
|---|---|---|
| *1* | *Practical class 1. Formulation of optimization problems. Methods of classical analysis for the study of the function of one variable.* | *Carry out research of necessary and sufficient conditions of existence of an extremum according to the received individual task. Search for extreme points of a nonlinear function of several variables in MathCAD.* |
| *2* | *Discussion of results of calculations, defence of work 1* | |
| *3* | *Practical class 2. Graphical solution of linear programming problems.* | *Carry out a graphical solution of linear programming problems in MathCAD in accordance with the obtained individual task. Application of standard MathCAD tools for solving the LP problem.* |

| | | |
|---|---|---|
| *4* | *Discussion of results of calculations, defence of work 2* | |
| *5* | *Search for extrema of function of one variable by numerical methods.* | *Search for the extrema of the function of one variable by the method of scanning, methods of excluding intervals in the environment of MS Excel in accordance with the obtained individual task.* |
| *6* | *Discussion of results of calculations, defence of work 3* | |
| *7* | *Practical class 4 (part 1). Investigation of numerical methods for finding the conditional extremum of the function of many variables (fastest descent methods, Levenberg-Marquardt, coordinate descent, Newtonian methods) using MS Excel software, PTC MathCAD software.* | *Carry out (according to the received individual task) finding values of a conditional extremum of function of many variables in the MS Excel, MathCAD environments. Draw conclusions about the peculiarities of these environments when searching for the optimum function.* |
| *8* | *Practical class 4 (part 2). Investigation of numerical methods for finding the conditional extremum of the function of many variables (fastest descent methods, Levenberg-Marquardt, coordinate descent, Newtonian methods) using Matlab Optimization Toolbox.* | *Carry out (according to the received individual task) finding the extrema of function of many variables in the Matlab Optimization Toolbox environment. Draw conclusions about the peculiarities of these environments when searching for the optimum function.* |
| *9* | *Discussion of results of calculations, defence of work 4* | |
| *10* | *Practical class 5. Planning the optimal supply of raw materials to the industrial group гтшеы: solving the transport problem of linear programming in MS Excel Solver.* | *Carry out in accordance with the received individual task planning the optimal supply of raw materials to the enterprises of the production association: to solve the transport problem of linear programming in the environment of MS Excel Solver.* |
| *11* | *Discussion of results of calculations, defence of work 5* | |
| *12* | *Defence of computational project* | |
| *13* | *Practical class 6. Numerical solution of discrete optimization problems.* | *Carry out (according to the received individual task) the search of extrema of problems of discrete optimization by a method of branches and borders in the MS Excel environment.* |
| *14* | *Discussion of results of calculations, defence of work 6* | |
| *15* | *Practical class 7. Investigation of modern probabilistic methods of extreme search* | *Carry out (according to the received individual task) the investigation research of modern probabilistic methods of search of an extremum on an example of genetic algorithm. To draw conclusions about the peculiarities of the influence of the parameters of the genetic algorithm on the results of optimization of these environments* |
| *16* | *Discussion of results of calculations, defence of work 7* | |
| *17* | *Modular control work* | |
| *18* | *Concluding session* | |

## 6. Students' Individual Work

*The student's Individual work during the semester includes additional study of lecture material, preparation of reports on computer classes, calculation work, preparation for the defense of practical tasks, modular control work and calculation work, preparation for the exam. The recommended number of hours allocated for preparation for these types of work:*

| *Type of the student's Individual work* | *Number of academic hours for training* |
|---|---|
| *Preparation for classroom studies: reteachingof lecture material, preparation of preliminary versions of programs for calculations in the classroom, preparation of reports on computer workshops* | *2-3 hours per week* |
| *Preapaption of the calculational project* | *10 hours* |
| *Preparation for the defense of the calculational project* | *4 hours* |
| *Preparation for modular control work (reteaching of material)* | *4 hours* |

## Policy and control

## 7. The policy of the discipline (educational component)

*In the normal mode of operation of the university, lectures and computer classes are held in classrooms. In mixed mode, lectures are conducted through the Sikorsky Distance distance learning platform, computer workshops - in computer classrooms. In distance mode, all classes are conducted through the distance learning platform Sikorsky Distance. Attendance at lectures and computer workshops is a must. At the beginning of each lecture, the lecturer can conduct a survey based on the materials of the previous lecture using interactive tools (Google Forms, menti.com, Kahoot, etc.). Before the next topic, the lecturer can send questions using interactive tools to determine the level of awareness of applicants on this topic, increase interest and engage students in solving examples.*

*Rules for the defence of computer works and calculational project:*

*1. Students who have correctly performed calculations are allowed to defend (in case of incorrectly performed calculations, they should be eliminated).*

*2. Defence takes place according to the schedule specified in item 5 on individual tasks.*

*3. After checking the task, the teacher puts a general assessment on the defense and the work is considered protected.*

*4. Untimely defense and presenting of work without good reason shall be penalized in accordance with the rules for awarding incentive and penalty points.*

*Rules for assigning incentive and penalty points:*

1. *Untimely presenting of a computer classes tasks (without a valid reason) is fined 1 point;*
2. *Untimely defence of work without good reason is fined 1 point;*
3. *For each week of delay with the submission of calculatiobnal project, 1 penalty point (but not more than 5 points) is accrued.*
4. *4. For modernization of works there are from 1 to 6 incentive points;*
5. *Up to 0.5 incentive points (but not more than 10 points per semester) are awarded for active work at the lecture.*

*Academic Integrity Policy: Determined by academic integrity policy and other provisions of the University's Code of Honor.*

## 8. Types of control and rating system for assessing learning outcomes

*Types of control are established in accordance with the Regulations on current, calendar and semester control of learning outcomes in Igor Sikorsky Kyiv Polytechnic Institute:*

*1. Current control: answers to the teacher's questions during computer classes, modular control work.*
*2. Calendar control: occurs twice a semester as monitoring of the current state of fulfillment of syllabus requirements.*
*3. Semester control: written pass-fail exam.*

***Rating system for assessing learning outcomes***

*1.1. The student's rating from the credit module is calculated based on a 100-point scale. The semester rating consists of points that the student receives for:*
*- work on a computer workshop (7 topics);*
*- writing a module test (MCR);*
*- performance of settlement work (PP).*

***2. Scoring criteria:***

*2.1.* ***Computer classes****. Weight point -* ***8 points****;*
*2.2.* ***Modular control****. Weight point -* ***30 points;***
*2.3.* ***Calculationional project****. Weight point -* ***14 points****.*

*3. The prerequisite for obtaining a positive assessment of the calendar control is the implementation of all work planned for this time (for the time of the calendar control). At the first calendar control (8th week) the student receives "credited" if his current rating is not less than 0.5 · 21 = 10 points. At the second calendar control (14th week) the student receives "credited" if his current rating is not less than 0.5 · 42 = 21 points and credited the calculationional project*
*Notes:*

1. *21 points is the maximum number of points that a student can score in 8 weeks*
2. *42 points is the maximum number of points that a student can score in 14 weeks*

*The maximum amount of points that a student can score during the semester is 60 points:*

$$RC = r_{compcl} + r_{module} + r_{ppcal\_proj} = 56+30+14 = 100 \text{ points}$$

*For the credit module to be credited, the student must have a rating of at least 60 points, defend all computer workshops, write a module control work and defend the calculation project. Students who have a rating of less than 60 points at the end of the semester, as well as those who want to increase the score, perform a test and this rating is final. The grade in this case is formed as follows: to the grade that the student received for the calculation project and modular test, is added a grade for a special additional credit test. The task of the test consists of 6-8 tasks of varying complexity. The maximum number of points for the test is 70.*

*The sum of points is transferred to the credit score according to the table below:*

*Table of correspondence of rating points to grades on the university scale:*

| *Scores* | *Final grade* |
|---|---|
| 100-95 | Excellent |

| | |
|---|---|
| 94-85 | Very good |
| 84-75 | Good |
| 74-65 | Satisfactory |
| 64-60 | Enough |
| Less then 60 | Unsatisfactorily |
| Admission conditions are not met | Non-admission |

## 9. Additional information on the discipline (educational component)

- *Requirements for the c alculational project, a list of questions for modular control work and pass-fail exam are given in the Google Classroom "Optimization of chemical engineering processes and systems" (Sikorsky-distance platform).*

Silabus compiled by an associate professor of the Department of Technology of Inorganic Substances, Water Treatment and General Chemical Technology:

Arcady Shakhnovsky, Ph.D.

Approved by the Department of Technology of Inorganic Substances, Water Treatment and General Chemical Technology (protocol № ___ from _____ 2021)

Approved by the Methodical Commission of the faculty (protocol № __ from _____. 2021)