Discipline Details

National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute"

Department of Ecology and Plant Polymers Technology

Mathematical modeling in ecology
Work Program of the Discipline (Silabus)

Discipline Details

Level of higher education	***First (bachelor's)***
Branch of knowledge	*16 Chemical and Bioengineering*
Specialty	*161 Chemical Technology and Engineering*
Educational program	*Industrial ecology and resource efficient cleaner technology*
Discipline status	*Selective*
Form of study	*Full-time (day)/ distance/ mixed*
Year of preparation, semester	*3rd year, spring semester*
The scope of discipline	*4 (120)*
Semester control / control measures	*Test*
Lessons schedule	*4 hours per week (2 hours of lectures and 2 hours of laboratory work)*
Language of instruction	*Ukrainian*
Information about course leader / teachers	*Lecturer: Ph.D., Associated professor Sirenko L.V., Laboratory work: Ph.D. Associated professor Radovenchik Y.V. - https://eco-paper.kpi.ua/pro-kafedru/vykladachi/radovenchik-yaroslav-vyacheslavovich.html*
Course placement	*https://do.ipo.kpi.ua/course/view.php?id=5313*

Academic Discipline Program

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

Mathematical modeling is currently one of the most important components of scientific and technological progress. No large-scale technological, ecological or economic project can be implemented without use of this methodology. Knowledge of the general principles of mathematical modeling in ecology, directions of modeling and forecasting of the state of the environment, methods of processing and analysis of experimental studies will allow to explain the results of experiments, perform specific calculations of the

main parameters of environmental pollution and apply mathematical modeling methods, in order to make management decisions based on process analysis, occurring in ecological systems.

The subject of the discipline *" Mathematical modeling in ecology "- application of mathematical models: numerical-analytical, empirical and statistical in order to formalize problems that arise in the process of monitoring and analyzing the state of environmental pollution.*

The goal of studying *" Mathematical modeling in ecology"- Students' assimilation of basic knowledge on issues of system analysis of complex processes in ecology, and making adequate management decisions based on them.*

According to the goal, training in this specialty requires students to develop the following competencies:

- the ability to apply knowledge in practical situations.

- the ability to use the provisions and methods of fundamental sciences to solve professional problems.

- the ability to use computing and information technologies to solve complex problems and practical problems in the field of chemical engineering.

In accordance with the requirements of the discipline " Mathematical modeling in ecology" students after mastering it must demonstrate the following program learning outcomes:

- to use modern computer technology , specialized software and information technology to solve complex problems and practical tasks in the field of chemical engineering, in particular, for calculations of equipment and processes of chemical production.

- to understand the basic environmental laws, rules and principles of environmental protection and nature management.

2. Pre-requisities and post-requisities of the discipline (place in the structural and logical scheme of the education according to the relevant educational program)

Interdisciplinary connections: the educational discipline "Mathematical modeling in ecology" is preceded by the educational disciplines of higher mathematics and information technologies. The educational discipline "Mathematical modeling in ecology" provides the discipline "Mathematical modeling and optimization of objects of chemical technology", diploma project and disciplines of the second master's level of higher education.

3. The content of the discipline

Section 1. *General description of the modeling problem in ecology*

The place and role of modeling problems in the complex of problems of analysis and forecasting of ecological processes. Systemic aspects of the study of ecological processes. General characteristics of the system modeling problem. Classification of systems modeling types.

Section 2. *Main directions of modeling and forecasting of ecological processes*

Physical basis of modeling and forecasting of environmental pollution processes. Derivation of the equation of turbulent diffusion and movement of harmful impurities in the atmosphere.

Numerical-analytical and empirical-statistical modeling methods in ecology. Expert systems in environmental problems.

4. Training materials and resources

4.1. Basic literature

1. *Yaskovets I.I., Protas N.M., Osypova T.Y., Kasatkin D.Y. MODELING AND FORECASTING THE STATE OF THE ENVIRONMENT [textbook] / I.I. Yaskovets, N.M. Protas, T.Y. Osipova, D.Y. Kasatkin // - K.: NUBiP of Ukraine, 2018. - 566 p.*

2. *Mathematical modeling of systems and processes / Pavlenko P.M., Filonenko S.F., Cherednikov O.M., Treytyak V.V. - K., NAU, 2017. - 392 p.*
3. *Modeling and optimization of systems: textbook / Dubovoy V. M., Kvetny R. N., Mikhalov O. I., Usov A. V. - Vinnytsia: "TD" Edelweiss", 2017. - 804 p.*
4. *Methodological instructions for performing calculation and graphic work and independent work from the course "Modeling and forecasting the state of the environment" for students of the training direction 6.040106 Ecology, environmental protection and balanced nature management. [Electronic resource] / L.V. Sirenko - Kyiv: NTUU "KPI", 2012.-http://library.kpi.ua.*
5. *Modeling and forecasting of the environment state: textbook / Lavryk V.I. - "Academy", 2010. - 400 p.*

4.2. Additional literature

6. *Dykhanov S.M. Modeling and forecasting of the environment state. Manual and collection of tasks for independent and individual work. – Odesa State Academy of Refrigeration, 2010. – 390 p*
7. *Modeling and forecasting of the state of the environment. Course of lectures. Specialty 101 "Ecology". / Compiler: O.V. Rybalova Kh: NUTZU, 2016. - 221p.*
8. *Geoinformation technologies in ecology: Study guide / Pitak I.V., Negadaylov A.A., Masikevychuk L.D., Shaporev V.P., Moiseev V.F./.– Chernivtsi:, 2012.– 273p.*
9. *Zhlukhtenko V.I., Nakonechnyi S.I. Probability theory and mathematical statistics: Teaching method. manual. In 2 chapters - Chapter 1. Theory of probabilities. - K.: KNEU, 2000. - 304 p.*
10. *Zhlukhtenko V.I., Nakonechnyi S.I. Probability theory and mathematical statistics: Teaching method. Manual. In 2 chapters – Chapter 2. Mathematical statistics. - K.: KNEU, 2001.-336 p.*
11. *Methodological instructions for conducting practical classes and performing independent work from the course "Methods of mathematical statistics in ecology" [Electronic resource] /Compiler Sirenko L.V. - Kyiv: NTUU»KPI», 2012.-http://library.kpi.ua.*
12. *Slipchenko V.G., Brydun E.V. etc.. Environmental and economic damages: quantitative assessment. Kyiv," Polytechnica", 2001.*

Informational internet resources

13. *Ministrty of Environmental Protection and Natural Resources of Ukraine- https://mepr.gov.ua/*
14. *http://www.eco-paper.kpi.ua/for-student*

Educational Content

5. Mastering methods of academic discipline (educational component)

Lectures

The lectures are aimed at: providing modern knowledge in the discipline "Mathematical modeling in ecology"; ensuring the active work of students during the lecture in order to form the necessary interest in the discipline, the development of independent creative thinking; accessibility for perception by the audience, clarification of all newly introduced terms and concepts; highlighting the main thoughts and provisions, emphasizing the conclusions.

№	Title of the lecture and a list of key issues (list of teaching aids, references to literature and tasks for independent work of students (IWS))	Hours
1	The place and role of modeling problems in the complex of problems of analysis and forecasting of ecological processes. Lit (1; 5; 6; 7). Task on IWS: give answers to control questions Lit. (4 p. 12-13)	2
2	Systemic aspects of the study of ecological processes. Lit (2; 5; 7). Tasks on IWS: give answers to control questions Lit. (4 p. 12-13)	2
3	General characteristics of the system modeling problem. Classification of systems modeling types. Lit (1; 2; 3). Task on IWS: get acquainted with the general scheme of building a model. Lit (7 p.29-49)	2
4	Analysis of physical phenomena underlying ecological processes and their mathematical description. Criteria for the turbulent motion of the atmosphere. Lit (1; 5; 6; 7). The task at the IWS: to get acquainted with anthropogenic changes in the climate of cities. Lit (5,6)	2
5	Numerical analytical methods of modeling and forecasting processes of environmental pollution. Derivation of the equation of turbulent diffusion and movement of harmful impurities in the atmosphere. Lit (1; 5; 6; 7). The task on IWS: to get acquainted with the assessment of water quality in river basins and reservoirs under conditions of anthropogenic influence. Lit (5; 7 - p 137-152)	2
6	Prognostic equations, their integration. Lit (1; 5; 6; 7). Task on IWS: give answers to control questions Lit. (4 p. 13-14)	2
7	Characteristics of turbulence and wind speed in the surface layer of the atmosphere. Lit (5; 7). Task on IWS: Numerical-analytical model of pollution of the air basin from a point source Lit. (1; 4; 7).	2
8	Turbulent diffusion equation for a water body Lit. (1; 5; 6; 7). Task on IWS: give answers to control questions Lit. (4 p. 13-14)	2
9	Methods of discretization of prognostic differential equations. Lit (1;7)	2
10	Simulation modeling methods in the study of complex ecological-social-economic systems. Tasks on IWS: The main stages of the simulation modeling process, advantages and disadvantages of the method. Lit (2;3;7 p.21-28).	2
11, 12	Statistical models of ecological processes. Determination of numerical characteristics of statistical distribution. Tasks on IWS: the law of large numbers Lit. (9 p. 75-99)	4
13	Prognostic pattern recognition scheme of background air pollution. Tasks on IWS: Primary statistical processing of experimental data. Lit (10, 11 p. 15-22).	2
14	Prognostic scheme of air pollution taking into account weather conditions and atmospheric stability. Lit (12). Task on IWS: give answers to control questions Lit. (7 p. 168)	2
15, 16	The scheme of linear regression. The method of least squares. Task on IWS: give answers to control questions. Lit (10 p. 173-220)	4
17	Application of expert systems for decision-making in environmental problems. General structure of the decision support system. Lit (5,6) Tasks on IWS: Tasks on SRS: familiarize with the general capabilities of GIS. Lit (8).	2
18	Determination of the parameters of the pollution process using a decision support system. Lit (5.6).	2

Laboratory classes

Laboratory works are aimed at consolidating the theoretical provisions of the credit module, acquired during lectures and in the process of studying educational information submitted for self-study. The main tasks of the cycle of laboratory works: to help students to systematize, consolidate and deepen the knowledge of a theoretical nature in the field of mathematical modeling and forecasting of the environment; teach students to use modeling knowledge to solve problems that arise in the process of control and analysis of environmental pollution; teach students of practically apply numerical-analytical, empirical methods and expert systems in the problems of mathematical modeling in ecology; teach students to work with scientific and reference literature.

№	Topic of the lesson	Classroom Hours/ Quantity
1	Forecast of the harmful impurities concentration spread from several sources on the industrial plane using a computer program that implements a generally accepted method. IWS task: prepare initial data for the job.	6
2	Work with computer MPC (maximum permissible concentration) of air, water, soil databases.	4
3	Determination of the maximum allowable discharge of substances into a water body using the computer program "SBROS". IWS task: prepare output data for MAD calculation (maximum allowable discharge).	6
4	Determination of the emission capacity of pollutants during the combustion of different fuels.	6
5	Statistical modeling and forecasting of air pollution	6
6	Decision-making in the tasks of choosing an adequate model for forecasting environmental situations.	6
7	Modular test work.	2
	Total hours	36

Student's Individual Work

Individual work takes 40% of the time studying the credit module, including test preparation. The main task of students' individual work is to master scientific knowledge in areas that are not included in the list of lecture questions by personal search for information, the formation of active interest in the creative approach in educational work.

№	Topic submitted for individual study	IWS Hours/ Quantity
1	General scheme of air pollution model construction. Lit. (7 p.29-49)	2
2	Anthropogenic climate change in cities. Lit. (5,6)	2
3	Assessment of water quality in river basins and reservoirs under conditions of anthropogenic impact. Theoretical foundations of calculation methods. Lit. (5; 7 p. 137-152).	2
4	Numerical-analytical model of pollution of the air basin from a point source Lit. (1; 4; 7).	2
5	The main stages of the simulation modeling process, advantages and disadvantages of the method. Lit (2;3;7 p.21-28)	2
6	The law of large numbers Lit. (9 p. 75-99)	2
7	Primary statistical processing of experimental data. Lit (10, 11 p. 15-22).	2
8	General features of GIS. Lit. (8)	4
9	Preparation for lectures	4
10	Preparation for laboratory works	8
11	Preparation for modular test work	2
12	Performance of test homework	10
13	Test	6
	Total hours	48

Individual Tasks

In order to deepen students' knowledge of the discipline, gain experience in individual work in mathematical modeling in ecology, it is proposed to perform an individual task in the form of test homework, which has the following targets:

- systematization and consolidation of knowledge acquired by students during the study of theoretical material,

- acquisition and consolidation of practical skills at individual work on the application of numerical and analytical methods in the problems of mathematical modeling of environmental pollution. Requirements for the structure, content and design of the work are given in Lit. (4).

Provision of program results by components of the educational component

Program result	Lecture classes	Practical and laboratory classes, individual assignments
To understand the basic environmental laws, rules and principles of environmental protection and nature management	**Lecture** 1. The place and role of modeling problems in the complex of problems of analysis and forecasting of ecological processes. **Lecture** 2. Systemic aspects of the study of ecological processes. **Lecture** 3. General characteristics of the system modeling problem. **Lecture** 4. Analysis of physical phenomena underlying ecological	Laboratory classes 2. Work with computer MPC (maximum permissible concentration) of air, water, soil databases. Laboratory classes 4. Determination of the emission capacity of pollutants during the combustion of different fuels. Laboratory classes 6. Decision-making in the tasks of choosing an adequate model for

	processes and their mathematical description. ***Lecture** 5. Numerical analytical methods of modeling and forecasting processes of environmental pollution* ***Lecture** 6. Prognostic equations, their integration.* ***Lecture** 7. Characteristics of turbulence and wind speed in the surface layer of the atmosphere* ***Lecture** 8. Turbulent diffusion equation for a water body .* ***Lecture** 13. Prognostic pattern recognition scheme of background air pollution.* ***Lecture** 14. Prognostic scheme of air pollution taking into account weather conditions and atmospheric stability.*	*forecasting environmental situations.* *Individual assignment (Calculation and graphic work)*
To use modern computer technology , specialized software and information technology to solve complex problems and practical tasks in the field of chemical engineering, in particular, for calculations of equipment and processes of chemical production	***Lecture 9.** Methods of discretization of prognostic differential equations* ***Lecture 10.** Simulation modeling methods in the study of complex ecological-social-economic systems* ***Lecture 11,12** Statistical models of ecological processes* ***Lecture 15, 16.** The scheme of linear regression* ***Lecture 17, 18.** Application of expert systems for decision-making in environmental problems*	*Laboratory classes 1. Forecast of the harmful impurities concentration spread from several sources on the industrial plane using a computer program that implements a generally accepted method.* *Laboratory classes 3 Determination of the maximum allowable discharge of substances into a water body using the computer program "SBROS".* *Laboratory classes 5. Statistical modeling and forecasting of air pollution*

Policy and Control

6. Academic discipline policy (educational component)

Rules for attending classes and behavior in class

Students are obliged to take an active part in the learning process, not to be late for classes and not to miss them without serious reason, not to interfere the teacher to conduct classes, not to be distracted by actions that are not related to the learning process.

Rules for reward and penalty points

- *Reward points can be awarded by the teacher only for the performance of creative work in the discipline or additional online profile courses with the appropriate certificate:*

- https://www.coursera.org/learn/problem-solving;

- https://www.coursera.org/learn/ecosystem-services.

Amount of reward points cannot exceed 10% of the rating scale.

- *Penalty points are not provided within the academic discipline.*

Policy of deadlines and rearrangements
In the event of arrears from the academic discipline or any force majeure circumstances, students should contact the teacher through available (provided by the teacher) communication channels to resolve issues and agree on an algorithm for actions to work out.

The policy of academic integrity
Plagiarism and other forms of dishonesty are not allowed. Plagiarism includes the lack of links when using printed and electronic materials, citations, opinions of other authors. Invalid hints and write-offs during test. Policy and principles of academic integrity are defined in Section 3 of the Code of Honor of the National Technical University of Ukraine " Igor Sikorsky Kyiv Polytechnic Institute ".
Read more: https://kpi.ua/code

Policy of academic behavior and ethics
Students must be tolerant, respect the opinions of others, formulate objections in the correct form.
Ethical behavior norms of students and employees are defined in Section 2 of the Code of Honor of the National Technical University of Ukraine " Igor Sikorsky Kyiv Polytechnic Institute ".
Read more: https://kpi.ua/code

7. Types of control and assessment rating system of learning outcomes (ARS)

Distribution of study time by types of classes and tasks in the discipline according to the working curriculum:

Semester	Study time		Distridution of study hours				Control measures		
	Credits	Acad. Hours	Lectures	Practical work	Lab. work	IWS	MCT	HTW	Semester control
6	4	120	36	-	36	48	1	1	Test

**MCT (modular test work)*
**HTW (home test work)*
For the full-time form of education, it is proposed to implement a rating system for assessing the success of students' assimilation of educational material of the credit module. The student's rating of the credit module "Mathematical Modeling in Ecology" consists of points receive for:
1) survey during lectures;
2) performance and protection of laboratory work;
3) control work;
4) test homework
Semester control – test.

System of rating points and evaluation criteria

1. Express control at lectures, number of answers 2.
- comprehensive answer -5 points,
- the answer has insignificant inaccuracies - 4 points,
- the answer is superficial, incomplete –3- 1 points,
- no answer - 0 points.
2. Execution of 6 laboratory works:
- correctly performed, designed and defended work – 10-9points;
- some insignificant shortcomings in the performance or at defense of work – 8-6 points;
- some certain shortcomings in the preparation, implementation and defense of work – 5-1 points;
- failure to perform work - 0 points,

3. Modular control work is evaluated with 15 points:

- full answer (not less than 90% of the required information) - 15-13 points;

- sufficiently complete answer (not less than 75% of the required information) or complete answer with minor inaccuracies - 12 - 9 points;

- incomplete answer (not less than 60% of the required information) and minor errors - 8- 6 points;

- superficial answer - 5-1points;

- no answer 0 points.

4. Home test work is evaluated with 15 points.

- all work requirements are met - 15-13 points;

- almost all requirements for work are fulfilled or there are insignificant errors - 12-9 points:

- there are shortcomings of the requirements of work and certain errors - 8-5 points;

- unsatisfactory work - 4-1 points,

- work not credited (work not done) - 0 points.

Calendar control: conducted twice a semester to monitor the current state of compliance with the requirements of the syllabus.

The condition of the first certification is to obtain at least 20 points and perform laboratory work (at the time of certification). The condition of the second certification is to obtain at least 40 points, perform all laboratory work (at the time of certification) and enroll in the HTW.

Thus, the rating semester scale of the discipline is:

$$R = 2 \cdot 5 + 6 \cdot 10 + 1 \cdot 15 + 1 \cdot 15 = 100 \text{ points}$$

Semester control: test.

To receive credit from the credit module "automatically" you need to have a rating at least 60 points. A rating of at least 40 points is a necessary condition for admission to the credit.

Students who scored a rating less than 0.6 R during the semester, as well as those who want to improve the overall rating, complete a credit test. At the same time, all the points they received during the semester are cancelled. The credit control work is estimated at 100 points.

At the test each task contains two theoretical questions. Each theoretical question is evaluated in 50 points.

System for estimation theoretical issues:

- "excellent", complete answer (at least 90% of the required information) 50-41 points;

- "good", a fairly complete answer (at least 75% of the required information or an answer with minor inaccuracies) 40-31 points;

- "satisfactory", incomplete answer (at least 60% of the required information and some errors) 30 - 21 points;

- "unsatisfactory", unsatisfactory answer 20- 0 points.

Rating points conformity table to grades on the university scale:

Applicant's rating	*University assessments scale of acquired competences level*
95...100	*Perfect*
85...94	*Very good*
75...84	*Fine*
65...74	*Satisfactorily*
60...64	*Enough*
Less than 60	*Unsatisfactorily*
R<40 or other conditions for test admission are not met	*Not allowed*

8. Additional information of the discipline (educational component)

Work program of the discipline (Silabus):

Compiled by: *prof., Ph.D, Sirenko L.V., Associated prof. Radovenchik Y.V*

Approved by the Department *_E and PPT (protocol №17_23.05.2024_)*

According to the *Methodical Commission of the Faculty of Chemical Engineering (protocol No 11 from_28.06.24)*