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

Department of machines and devices of chemical and oil refining industries

BASICS OF MEMBRANE TECHNOLOGY

Working program of the academic discipline (Syllabus)

Details of the academic discipline	
Level of higher education	***First (undergraduate)***
Branch of knowledge	*13 Mechanical engineering*
Specialty	*133 Industrial engineering*
Educational program	*Computer-integrated technologies of chemical engineering equipment design*
Discipline status	*Selective*
Form of education	*daytime*
Year of training, semester	*4th year, spring semester*
Scope of the discipline	*4 ECTS credits*
Semester control/ control measures	*Assessment, MKR, calculation work*
Lessons schedule	
Language of teaching	*Ukrainian*
Information about the course leader / teachers	Lecturer:*Ph.D., Serhiy Valeriyovych Gulienko,sergiiguliienko@gmail.com, +38504488173* Practical:*Ph.D., Serhiy Valeriyovych Gulienko,sergiiguliienko@gmail.com, +38504488173* Laboratory:not provided for in the curriculum
Placement of the course	

Program of educational discipline

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

Membrane processes are relatively new and highly effective methods of separating mixtures into components, which can be applied to both liquid and gaseous systems. Compared to traditional separation methods, which are studied in detail in the course "Processes and equipment of chemical technologies", membrane methods have a number of advantages, in particular, such as high separation efficiency, absence of reagents, relatively low energy costs, and simplicity of equipment. Such advantages of these processes led to their wide use in the chemical, pharmaceutical, biotechnological, food industries, as well as for environmental protection. However, a number of issues related to membrane technology remain unresolved, in addition, new problems have arisen related to the formation of concentrates, used membrane modules, etc. The spread of membrane processes in the last 30-50 years and unsolved problems raise the need of these industries for specialists who have the competences in the design, operation and modernization of membrane processes and equipment and are able to solve the urgent problems of this industry. Therefore, the educational component "Fundamentals of membrane technology" is offered for study for students studying in the specialty 133 Industrial mechanical engineering, educational program Computer-integrated technologies of chemical engineering equipment design.

Membrane processes as separation methods are relatively new. As already mentioned, in the middle of the 20th century, membrane filtration was not considered a technically important separation process. Today, membrane processes are widely used and the scope of their application is constantly expanding. From an economic point of view, the turn of the 20th and 19th centuries is a transitional period between

the development of membrane processes of the first generation, such as microfiltration (MF), ultrafiltration (UF), reverse osmosis (RO), electrodialysis (ED) and dialysis, and membrane processes of the second generation, such as gas separation (GR), pervaporation (PV), membrane distillation (MD) and separation using liquid membranes (LM). Membrane processes are classified according to the type of the main driving force of the process. The driving force of membrane processes is a gradient of chemical or electrochemical potential. However, for technical calculations of such processes, as well as for the rest of the exchange processes, the gradient of the factor determining the speed of this process, such as the gradient of pressure, temperature, etc., is taken as the driving force of the membrane process. Accordingly, baromembrane processes, diffusion-membrane processes, electro-membrane processes and thermo-membrane processes are distinguished.

The educational component "Fundamentals of Membrane Technology" involves the study of membrane processes, according to the specified classification. Issues of operation of membrane equipment, membrane manufacturing methods and prospects for the development of membrane technology are also considered.

The subject of the educational component "Fundamentals of Membrane Technology" is the regularities and practical application of membrane separation processes.

The purpose of the educational component "Fundamentals of Membrane Technology" is to form a set of knowledge:

- To know and understand the principles of technological, fundamental and technical sciences that underlie membrane technology.

- To know and understand the principles, approaches and methods of membrane technology and the prospects for their development, to be able to analyze engineering objects, processes and methods.

- Know the typical designs of membrane devices, their classification, areas of application, principles and methods of calculation and be able to make their informed choice.

According to the goal, bachelor's training in this specialty requires strengthening the competencies formed by students:

- Ability to apply fundamental scientific facts, concepts, theories, principles to solve professional tasks and practical problems in membrane technology.

- The ability to evaluate the technical and economic efficiency of typical membrane systems and their components based on the application of analytical methods, comparison of analogues and the use of available data.

- The ability to determine the parameters of membrane processes and to make a rational choice of equipment for their implementation and to determine the modes of its operation in given production conditions.

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

The educational component "Fundamentals of Membrane Technology" is optional.

The requirements for starting the study include Basic knowledge obtained during the first three training courses, in particular, knowledge of the educational components: "Fundamentals of chemical engineering", "Transfer processes in solid media", "Processes and equipment of chemical technology".

The study of the discipline will be useful for diploma design, as well as when learning the material of a number of master's training disciplines, primarily "Synthesis and Separation Process Modeling" and "Innovative Materials Cleaning and Processing Technologies"

3. Content of the academic discipline

Chapter 1. Membrane processes as a component of chemical and oil refining industries.

Topic 1.1. The essence of membrane processes

The essence of methods of separation of liquid and gaseous mixtures using semipermeable membranes. The history of the development of membrane processes.

Topic 1.2. Classification of membrane processes

Classification and characteristics of membrane separation processes. The use of membrane processes in the chemical and oil refining industry and their comparison with traditional separation methods.

Topic 1.3 Types of membranes and membrane devices

Classification of membranes. Membrane manufacturing methods. Typical designs of membrane devices.

Chapter 2. Membrane processes.

Topic 2.1. Baromembrane processes.

Osmosis. Reverse osmosis. Models and mechanisms of reverse osmosis. Principles of process calculation. Microfiltration. Ultrafiltration. Nanofiltration.

Topic 2.2. Diffusion-membrane processes.

Membrane gas separation. Gas diffusion in porous and non-porous membranes. Pervaporation. Dialysis. Conventional and Donnan dialysis. Dialysis membranes.

Topic 2.3. Thermomembrane processes.

Membrane distillation.

Topic 2.4. Electromembrane processes.

Electrodialysis.

Chapter 3. The practice of using membrane processes in the chemical and oil refining industry

Topic 3.1. Polarization phenomena and contamination of membranes

Polarization phenomena and deposits on the surface of membranes. Operation of membrane equipment. Membrane cleaning and regeneration methods.

Topic 3.2. Schematic diagrams of membrane separation

Schematic diagrams of membrane separation. Work of cascades. Examples of cascades. Preparation of drinking water. Wastewater treatment. The use of membranes in medicine. Separation of azeotropic and thermolabile mixtures. Removal of vapors of organic substances. Dehydration of ethylene.

Topic 3.3. Prospects for the development of membrane processes

The main directions of modern research of membrane processes and their prospects.

4. Educational materials and resources

Basic literature:

1. *Modeling of membrane separation processes [Electronic resource]: study guide for students of specialty 133 "Industrial mechanical engineering", specialization "Engineering, computer modeling and equipment design of chemical and oil refining industries" / KPI named after Igor Sikorskyi; structure. S. V. Gulienko. – Electronic text data (1 file: 3.25 MB). – Kyiv: KPI named after Igor Sikorskyi, 2017. – 166 p. – Title from the screen.*

2. *Modeling of processes of membrane separation: workshop on the educational discipline [Electronic resource]: training. manual for students specialty 133 "Industry of mechanical engineering", specialization "Engineering, computer modeling and equipment design of chemical and oil refining industries" / KPI named after Igor Sikorskyi; comp.: S.V. Gulienko. – Electronic text data (1 file: 2.27 MB). – Kyiv: KPI named after Igor Sikorskyi, 2018. – 104 p.*
3. *Gulienko, S. V. Regeneration of rolled membrane modules of water treatment systems [Electronic resource] : monograph / S. V. Gulienko, Y. M. Kornienko; KPI named after Igor Sikorsky. – Electronic text data (1 file: 4.5 MB). – Kyiv: KPI named after Igor Sikorskyi, 2017. – 207 p. – Title from the screen.*
4. *Kornienko Y.M. Processes and equipment of chemical technology [Text]: tutorial. / Y.M. Kornienko, Yu.Yu. Lukach, I.O. Mikulonok et al.. - K.: NTUU "KPI", 2011. - Part 2. - 416 p.*

***Additional literature**:*

1. *Study of the process of reverse osmosis. Methodological guidelines for conducting scientific research work of students from the credit module "Modeling of membrane separation processes" [Electronic resource]: / NTUU "KPI"; structure. S.V. Gulienko– Kyiv: KPI named after Igor Sikorskyi, 2017. – 14 p.*
2. *Research on membrane separation of gases / Composer: H.L. Ryabtsev, T.A. Vozniuk, - 2008.*
3. *Algorithm for calculation of reverse osmosis and ultrafiltration membrane devices / Compendium. I.O. Mikulonok - 1995.*
4. *Gulienko S. V. The process of regeneration of rolled membrane modules: diss. ... candidate technical Sciences: 05.17.08 – processes and equipment of chemical technology / Serhiy Valeriyovych Gulienko. - Kyiv, 2016. - 214 p.*
5. *Huliienko SV Korniienko YM, Gatilov KO (2020). Modern trends in the mathematical simulation of pressure-driven membrane processes. Journal of Engineering Sciences, Vol. 7(1), pp. F1–F21, doi: 10.21272/jes.2020.7(1).f1*
6. *Huliienko S., Leshchenko O. (2019). Influence of operating pressure on concentration polarization layer resistance in reverse osmosis. Ukrainian food journal. Vol. 8., Is. 1, pp. 119-132.*
7. *https://www.sciencedirect.com/journal/advanced-membranes*
8. *https://www.sciencedirect.com/journal/journal-of-membrane-science*
9. *https://www.sciencedirect.com/journal/desalination*
10. *https://www.sciencedirect.com/journal/journal-of-membrane-science-letters*
11. *https://www.mdpi.com/journal/membranes*
12. *http://www.msrjournal.com/*
13. *https://www.sciencedirect.com/journal/membrane-technology*
14. *https://www.sciencedirect.com/journal/separation-and-purification-technology*
15. *https://www.youtube.com/watch?v=qaUQE8OkEjo&list=PL86konoyyLTZDlHM_daQFLJYq0fMhY7sy*

(Educational content

5. Methods of mastering an educational discipline (educational component)

Lecture classes

Lectures are aimed at:

- *provision of modern, integral, interdependent knowledge in the discipline "Fundamentals of membrane technology", the level of which is determined by the target setting for each specific topic;*
- *ensuring creative work of students together with the teacher during the lecture;*
- *education of students' professional and business qualities and development of their independent creative thinking;*
- *forming the necessary interest in students and providing direction for independent work;*
- *definition at the current level of scientific development in the field of membrane technology;*
- *reflection of the methodical processing of the material (highlighting of the main*

provisions, conclusions, recommendations, their wording is clear and adequate);

- the use of visual materials for demonstration, combining them, if possible, with the demonstration of research results;

- teaching research materials in a clear and high-quality language with observance of structural and logical connections, clarification of all newly introduced terms and concepts;

- accessibility for perception by this audience.

No. z/p	**The name of the topic of the lecture and the list of main questions (list of didactic tools, references to the literature and tasks on the SRS)**	**Hour**
1	*Lecture 1. The essence of methods of separation of liquid and gaseous mixtures using semipermeable membranes. The history of the development of membrane processes.* *Literature [1, 4]* *Tasks for SRS: Traditional methods of separation of mixtures [4].*	2
2	*Lecture 2. Basic concepts and characteristics of membrane separation processes. Classification of membrane separation processes.* *Literature [1, 4]* *Tasks for SRS: Driving forces of membrane processes [1, 4]*	2
3	*Lecture 3. Membranes for baromembrane processes. Membrane manufacturing methods* *Literature [1, 4]* *Tasks for SRS: Unconventional membrane materials [7-14]*	2
4	*Lecture 4. Design of devices for membrane processes* *Literature [1, 4]* *Tasks for SRS: Newest designs of membrane devices [7-14]*	2
5	*Lecture 5. Baromembrane processes. Osmosis. Osmotic pressure.* *Literature [1, 4]* *Tasks for SRS: Refined equations for calculating osmotic pressure [7-14]*	2
6	*Lecture 6. Reverse osmosis. Nanofiltration.* *Literature [1, 4]* *Tasks for SRS: Membranes for nanofiltration [7-14]*	2
7	*Lecture 7. Microfiltration. Ultrafiltration.* *Literature [1, 4]* *Tasks for SRS: Industrial and laboratory use of processes [1, 4]*	2
8	*Lecture 8. Diffusion-membrane processes. Membrane gas separation in porous and non-porous membranes.* *Literature [1, 4]* *Tasks for SRS: Membranes for gas separation [7-14]*	2
9	*Lecture 9. Pervaporation* *Literature [1, 4]* *Tasks for SRS: Membranes for pervaporation [7-14]*	2
10	*Lecture 10. Dialysis. Conventional and Donnan dialysis.* *Literature [1, 4]* *Tasks for SRS: Dialysis membranes*	**2**
11	*Lecture 11. Separation using liquid membranes* *Literature [1, 4]*	**2**
12	*Lecture 12. Thermomembrane processes. Membrane distillation.* *Literature [1, 4]* *Tasks for SRS: Membranes for membrane distillation*	**2**
13	*Lecture 13. Electromembrane processes. Electrodialysis.* *Literature [1, 4]* *Tasks for SRS: Membranes for electrodialysis [1, 4]*	**2**
14	*Lecture 14. Concentration polarization. Polarization phenomena during*	**2**

	electrodialysis and membrane distillation *Literature [1, 3]*	
15	*Lecture 15. Contamination of the membrane surface.* *Literature [1, 3]*	***2***
16	*Lecture 16. Methods of reducing the negative effects of concentration polarization and pollution.* *Literature [1, 3]* *Task for SRS: Recommendations of membrane manufacturers on regeneration [3]*	***2***
17	*Lecture 17. Schematic diagrams of membrane separation. Work of cascades. Examples of practical application of membrane processes.* *Literature [1, 3]* *Tasks for SRS: Constructive and hardware design of membrane separation systems [7-14]*	***2***
18	*Lecture 18. Prospects for the development of membrane processes* *Literature [7-14]*	***2***
	In total	***36***

Practical training

In the system of professional training of students from this educational component, practical classes occupy 33% of the classroom load. As a supplement to the lecture course, they lay and form the foundations of the bachelor's qualification. The content of these classes and the method of conducting them should ensure the development of the creative activity of the individual. They develop technical thinking and the ability to use special terminology, allow you to test knowledge, therefore this type of work is an important means of operational feedback. Practical classes should perform not only cognitive and educational functions, but also contribute to the growth of students as creative workers.

The main tasks of the cycle of practical classes:

- *help students systematize, consolidate and deepen knowledge of a theoretical nature in the field of membrane technologies;*
- *to teachstudents in the methods of solving practical tasks, to promote the mastery of skills and abilities to perform calculations, graphic and other tasks;*
- *to teachtheir work with scientific and reference literature;*
- *to form skillsto learn independently, that is, to master the methods, methods and techniques of self-learning, self-development and self-control.*

No. z/p	***Name of the subject of the practical session and list of main questions (a list of didactic support, references to the literature and tasks on the SRS)***	***Hour***
1	*Practical lesson 1.* *Calculation of the material balance of the membrane apparatus* *Determination of flow rates and concentrations of dissolved substances in streams* *Literature [2]*	*2*
2	*Practical lesson 2.* *Calculation of a cascade of membrane devices* *Determination of the number of devices in the first and subsequent sections. Determination of the number of sections.* *Literature: [2]*	*2*
3	*Practical lesson 3.* *Calculation of the apparatus for separation of gas mixtures*	*2*

	Material balance of the device. Determination of membrane surface area References: [2]	
4-5	*Practical lesson 4-5.* *Calculation of the reverse osmosis apparatus* *Material balance. Approximate calculation of the membrane surface area and design calculation of the reverse osmosis apparatus. Refined calculation of the surface area of membranes in a reverse osmosis device* *Literature: [2]*	*4*
6-7	*Practical lesson 6-7.* *Calculation of the apparatus for ultrafiltration* *Material balance. Approximate calculation of the surface area of membranes and design calculation of an ultrafiltration device for the separation of biological solutions. Detailed calculation of the surface area of membranes and design calculation of an ultrafiltration device for the separation of biological solutions.* *Literature: [2]*	*4*
8	*Modular control work. Protection of calculation work*	*2*
9	*Test*	*2*
	In total	*18*

6. Independent work of student

Independent work takes 55% of the time of studying the educational component, including preparation for the assessment, modular control work and preparation of the essay. The main task of students' independent work is to acquire knowledge from the course that was not included in the list of lecture questions by personally searching for information, forming an active interest in a creative approach to educational work. In the process of independent work within the framework of the educational component, the student must learn to analyze modern thermodynamic methods used in chemical engineering.

No. z/p	*The name of the topic submitted for independent processing*	*Number of hours of SRS*
1	*Chapter 1. Membrane processes as a component of chemical and oil refining industries.* *Traditional methods of separation of mixtures* *Driving forces of membrane processes* *Unconventional membrane materials* *The latest designs of membrane devices* *Literature [1-4]*	*11*
2	*Chapter 2. Membrane processes.* *Refined equations for calculating osmotic pressure Membranes for nanofiltration* *Industrial and laboratory use of processes* *Membranes for gas separation* *Membranes for pervaporation* *Dialysis membranes* *Membranes for membrane distillation* *Literature [1-5]*	*21*
3	*Chapter 3. The practice of using membrane processes in the chemical and oil refining industry.*	*12*

	Membrane manufacturers' recommendations for regeneration *Constructive and hardware design of membrane separation systems* *Literature [1-5]*	
5	*Execution of calculation work*	*15*
6	*Preparation for the test*	*6*
	Hours in general	*66*

Policy and control

7. Policy of academic discipline (educational component)

Rules of attending classes and behavior in classes

Attending classes is a mandatory component of the assessment. Students are obliged to take an active part in the educational process, not to be late for classes and not to miss them without a good reason, not to interfere with the teacher conducting classes, not to be distracted by actions unrelated to the educational process. When solving problems in practical classes, students can use any sources of information and means of calculations. All tasks are performed individually.

Rules for the protection of individual tasks

The curriculum provides for an individual lesson in calculation work. The calculation work is the calculation of the membrane device according to the standard method [2, 3] with justification of the chosen method and analysis of the calculation results

review of scientific articles (for example, from [7, 8]) on a specific topic. The abstract is defended in the form of a short (up to 3 minutes) oral report.

Rules for assigning incentive and penalty points

- *incentive points can be awarded by the teacher exclusively for the performance of creative works in the discipline or additional completion of online specialized courses with the receipt of the appropriate certificate:*

But their sum cannot exceed 25% of the rating scale.

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

Policy of deadlines and rescheduling

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 problematic issues and agree on an algorithm of actions for practice.

Policy of academic integrity

Plagiarism and other forms of dishonest work are unacceptable. Plagiarism includes the absence of references for the use of printed and electronic materials, quotes, opinions of other authors. Inadmissible tips and write-offs during writing tests, conducting classes; passing the exam for another graduate student; copying materials protected by the copyright system without the permission of the author of the work.

The policy and principles of academic integrity are defined in Chapter 3 of the Code of Honor of the National Technical University of Ukraine "Ihor Sikorsky Kyiv Polytechnic Institute". More details:https://kpi.ua/code

Policy of academic behavior and ethics

Students should be tolerant, respect the opinions of others, formulate objections in the correct form, constructively support feedback during classes.

Standards of ethical behavior of students and employees are defined in Chapter 2 of the Code of Honor of the National Technical University of Ukraine "Ihor Sikorskyi Kyiv Polytechnic Institute". More details:https://kpi.ua/code

8. Types of control and rating system for evaluating learning outcomes (RSO)

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

Semester	Training time		Distribution of study hours				Control measures		
	Credits	Acad. hours	Lectures	Practical	Lab. do	SRS	MKR	RR.	Semester control
6	4	120	36	18	–	66	-	1	test

The student's rating in the discipline consists of the points he receives for: completing 16 tasks in practical classes, defending the essay and MKR.
Semester control is credit.

System of rating (weighted) points and evaluation criteria

The system of rating points and evaluation criteria:

Performing tasks in practical classes.

The weighted score is 9. The maximum number of points for practical classes is 7·9=63.

Execution and defense of the abstract. Weight score 20.

Modular control work. Weight score 17

Credit is issued based on the results of work in the semester.

A student who received at least 60 points in the semester can take part in credit work to get a higher point. In this case, the points obtained by him on the control work with the addition of 50% of the points obtained in the semester are final.

The credit control work (if necessary) is evaluated out of 70 points. The control task consists of two theoretical tasks.

Each task is evaluated out of 35 points according to the following criteria:

- *excellent performance of the task, fluency in defense material - 32-34 points.*
- *good level of performance, correct answers to questions when defending the task - 25-30 points.*
- *a sufficient level of task performance, the presence of minorinaccuracies in answers - 20-22 points.*
- *poor quality of work, ignorance of theoretical material - 0 points.*

The condition of the first attestation is obtaining at least 20 points and completing 50% of practical work (at the time of attestation). The condition for the second attestation is to obtain at least 36 points and complete 75% of practical work (at the time of attestation).

The sum of the points received by the student is transferred to the examination grade according to the table:

Scores	***Rating***
95...100	*perfectly*
85...94	*very good*

75...84	*fine*
65...74	*satisfactorily*
60...64	*enough*
RD<60	*unsatisfactorily*
Admission conditions not met	*not allowed*

9. Additional information on the discipline (educational component)

An approximate list of questions that are submitted for semester control

1. *To analyze the history of the development of membrane processes*
2. *Explain the essence of the methods of separation of liquid and gaseous mixtures using semipermeable membranes*
3. *Analyze the definition of membrane and explain basic terminology related to membrane processes.*
4. *Explain the classification of membrane separation processes.*
5. *Analyze types of membranes.*
6. *Give a general assessment of baromembrane processes*
7. *Analyze the phenomenon of osmosis and conditions of osmotic equilibrium (osmotic pressure)*
8. *Explain the process of reverse osmosis*
9. *Explain the practical application of the reverse osmosis process.*
10. *Analyze the process of microfiltration*
11. *Analyze the ultrafiltration process.*
12. *Analyze methods of manufacturing membranes*
13. *Analyze the designs of flat-frame membrane modules*
14. *Analyze the designs of pipe membrane modules*
15. *Analyze the designs of spiral membrane modules*
16. *Analyze the designs of hollow fiber modules*
17. *Give a general assessment of diffusion-membrane processes*
18. *Analyze the process of gas separation in porous membranes*
19. *Analyze the process of gas separation using non-porous membranes*
20. *Analyze the pervaporation process.*
21. *Analyze the process of dialysis*
22. *Analyze the Donnan effect*
23. *Analyze the process of membrane distillation*
24. *Analyze the parameters of membrane distillation*
25. *Analyze the application of membrane distillation*
26. *Analyze the electrodialysis process*
27. *Analyze electrodialysis parameters*
28. *Analyze the use of electrodialysis*
29. *Analyze the resistance to the transfer of substances through the membrane*
30. *Analyze the phenomenon of concentration polarization*
31. *Explain the features of concentration polarization in baromembrane processes*
32. *Explain polarization phenomena during electrodialysis and membrane distillation*
33. *To analyze the causes of the flow drop in baromembrane processes*
34. *Explain the use of pretreatment of separated solutions to reduce the effect of concentration polarization*
35. *Explain the use of changes in membrane properties and mode parameters in the module to reduce the effect of concentration polarization*
36. *Analyze methods of membrane regeneration*
37. *Explain the principle schemes of membrane separation*
38. *Explain the cascade modes of operation of membrane equipment*
39. *Give examples of membrane separation schemes*

40. To analyze the prospects for the development of membrane processes

Working program of the academic discipline (syllabus):

Foldedassociate professor MAHNV, Ph.D., Assoc. Serhii GULIENKO

Approvedby the MAHNV Department (protocol No. 19 dated 17.05.2023)

Agreedby the methodical committee of the faculty (protocol No. 10 dated 05/26/2023)