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

Department of Inorganic Substances Technology, Water Treatment and General Chemical Technology

Modern materials in membrane technologies

Work programme of the educational component (Syllabus)

Details of the educational component	
Level of higher education	*Second (master's) degree*
Field of knowledge	*16 Chemical Engineering and Bioengineering*
Specialty	*161 Chemical technology and engineering*
Educational scientific program	*Chemical Technology and Engineering*
The status of the educational component	*Optional*
Form of education	*Full-time (day)*
Year of training, semester	*2nd year, autumn semester*
The scope of the educational component	*4 ECTS credits / 120 hours (lectures – 18 hours, laboratory classes – 36 hours, self-studying – 66 hours)*
Semester control / control measures	*Credit / Module test / Homework test*
Class schedule	*Lecture 2 hours per two weeks (1 class per two weeks), laboratory work 2 hours per week (2 classes per two weeks) according to the schedule on rozklad.kpi.ua*
Language	*English*
Information about the course leader / teachers	*Lecture:* *Svitlana Kyrii, kyrii.svitlana@lll.kpi.ua* *Laboratory works:* *Svitlana Kyrii, kyrii.svitlana@lll.kpi.ua*
Placement of the course	*Google Classroom (Google G Suite for Education, domainLLL.kpi.ua, Sikorsky-distance platform).* *Educational component "Modern materials in membrane technologies"* *https://classroom.google.com/c/NzA0ODgyMzg5ODYw?cjc=jcwfbc5* *- course code – jcwfbc5*

Educational component program

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

The teaching of the educational component "Modern materials in membrane technologies" to Master's degree students is due to the need to provide students with knowledge covering the field of chemical materials science and nanotechnology, in particular, the creation of polymeric and ceramic membranes for micro-, ultra-, nanofiltration membranes for a wide range of applications.

Subjects of the educational component: *polymer, cellulose, ceramic and composite membranes, modern methods of membrane formation and synthesis, methods of research of membrane materials, membrane modules, membrane structures, membrane processes.*
The educational component aims *to equip students with knowledge of materials science, focusing on modern materials and the physical and chemical principles behind contemporary membrane material synthesis methods.*
The study of the educational component enhances the following programme ***learning outcomes****:*

- *Ability to present scientific results in English in the form of a scientific discussion (**CP 1**);*
- *Ability to write scientific articles/projects/reports in English (**CP 3**);*
- *Ability to analyse and select the latest and most relevant literature for the purpose of critical analysis of modern research in the field of chemical materials science (**CP 4**);*
- *Ability to synthesise membrane materials, study their physical and chemical properties and transport characteristics (**CP 5**);*
- *Ability to develop adapted synthesis methods/research methods in the field of chemical materials science (**CP 7**).*

The study of the educational component enhances the following ***programme learning outcomes****:*

- *Fluency in technical terms in the field of chemical materials science in English (**CPO 1**);*
- *Prepare scientific articles/projects/reports in English (**CPO 3**);*
- *Analyse and select the latest and most relevant literature for critical analysis of current research in the field of chemical materials science (**CPO 4**);*
- *Synthesise membrane materials, investigate their physical and chemical properties and transport characteristics (**CPO 5**);*
- *Develop adapted synthesis methods/research methods in the field of chemical materials science (**CPO 8**).*

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

Pre-qualifications: *Knowledge of English (at least B2 level), Bachelor's degree in Chemical Technology and Engineering, speciality 161.*

Post-qualifications:

Experimental methods in research	*Ability to implement the modern materials for membrane technologies at chemical and technological production facilities*
Scientific and Research practice	*Ability to perform a qualitative search in scientific and technical literature, patents, databases, and other sources to find the necessary information on chemical technology, purification processes and equipment, and production of chemicals and materials based on them, to systematise and analyse and evaluate relevant information*
Performing master thesis	*Ability to apply modern solutions in the field of materials science, water treatment and water purification.* *Ability to identify and solve problems in the field of chemical processes, evaluate and ensure the quality of research. Ability to develop technological indicators for the production and practical application of advanced technologies and materials.*

3. Content of the educational component

Theme 1. Fundamentals of material science for membrane design

Characteristics of membrane materials. The importance of the chemical structure of materials, physical properties of gases and liquids, and the interaction between gases/liquids and the membrane material. The structure-property relationship. Transport mechanisms in the context of material selection. Membrane manufacturing technologies. Performance and durability of membranes and the influence of starting materials on them. Membrane application and materials selection for their manufacture. Sustainability and environmental impact in the context of the development and processing of membrane materials. Principles of environmentally friendly membrane materials.

Theme 2. Polymeric membrane materials

Polymeric membrane materials, their synthesis, features, application, advantages and disadvantages: polyvinylidene difluoride, polypropylene, polyamide, polysulfone, polyester sulfone, polyvinyl chloride, polyetherimide, polyvinyl alcohol, polylactic acid, cellulose-based materials, chitosan, alginates, polybutylene succinate. Technologies for polymeric membranes production with an emphasis on material properties. Modification of polymeric membranes. Strategies for chemical modification of the membrane surface. Chemical and physical modification.

Theme 3. Ceramic membrane materials

Ceramic membrane materials, their synthesis, features, applications, advantages and disadvantages: metal oxides (aluminium, titanium, zirconium, silicon, etc.); zeolites; clays (kaolin, bentonite, fire clays, porcelain clays, etc.); silicon carbide; carbon-based materials (carbon nanotubes, graphenes, metal-organic frameworks (MOFs), MXenes, etc.). Additives and modifiers for ceramic membranes, their role, impact and application features. Technologies for the ceramic membrane production with a focus on material properties. Features of materials for the selective layer, their synthesis and technologies of application to the ceramic matrix. Technology of ceramic membranes 3D printing and specifics of selection and preparation of materials for their production. Modification of ceramic membranes. Strategies for chemical modification of the membrane surface. Chemical and physical modification.

Theme 4. Composite membrane materials

Features of the combination of polymeric and inorganic materials for composite membranes. Imparting specific properties to composite membranes (mechanical strength, resistance to contamination, hydrophilicity, water permeability, antibacterial, etc.) Interfacial compatibility of composite membrane materials.

Theme 5. The modern materials and membranes based on them

Covalent organic frameworks (COFs). Biomimetic materials. Electroactive membranes. Membranes based on ionic liquid. "Green" materials for membranes.

4. Educational materials and resources

The teaching materials listed below are available at the University Library and at the library of the Department of Technology of Inorganic Substances, Water Treatment and General Chemical Technology at https://classroom.google.com/c/NzA0ODgyMzg5ODYw?cjc=jcwfbc5. The basic literature is mandatory, while other materials are optional. The modules and topics that the student should read independently are indicated by the teacher during lectures and laboratory classes.

Basic

1. Hongmei Yuan, Jianguo Liu, Xinghua Zhang et al. Recent advances in membrane-based materials for desalination and gas separation, Journal of Cleaner Production, Vol. 387, 2023, 135845, https://doi.org/10.1016/j.jclepro.2023.135845/.
https://classroom.google.com/u/1/w/NzA0ODgyMzg5ODYw/tc/NzU5Mjk5NDI0NDcy

2. Advanced Membrane Science and Technology for Sustainable Energy and Environmental Application, Woodhead Publishing Series in Energy 2011, Pages i-iii , https://doi.org/10.1533/9780857093790.frontmatter.
https://classroom.google.com/u/1/w/NzA0ODgyMzg5ODYw/tc/NzU5Mjk5NDI0NDcy

3. Syafiq, Sharip Mohd, Sazali Norazlianie, Jamaludin Ahmad Shahir, M. Atif, Aziz Farhana and Wan Salleh Wan Norharyati. "Current Advancement by Membrane Technology: A Review." (2019).
https://classroom.google.com/u/1/w/NzA0ODgyMzg5ODYw/tc/NzU5Mjk5NDI0NDcy

Optional

1. Ludovic F. Dumée, Mohtada Sadrzadeh and Mohammad Mahdi A. Shirazi. Green Membrane Technologies towards Environmental Sustainability, 2023, Elsevier Inc., 625 p. https://www.sciencedirect.com/book/9780323951654/green-membrane-technologies-towards-environmental-sustainability.
https://classroom.google.com/u/1/w/NzA0ODgyMzg5ODYw/tc/NzU5Mjk5NDI0NDcy

2. Донцова Т. А., Кузьмінчук А. В., Янушевська О. І., Літинська М. І., Кирій С.О. Мембранні технології: Керамічні мембрани на основі мінеральної сировини : монографія. – Київ : КПІ ім. Ігоря Сікорського, Вид-во «Політехніка», 2023. – 181 с. ISBN 978-966-990-092-0
https://classroom.google.com/u/1/w/NzA0ODgyMzg5ODYw/tc/NzU5Mjk5NDI0NDcy

Information resources

1. https://www.dupont.com/resource-center.html?BU=water-solutions

Educational content

5. Methods of learning the educational component

Lectures

Lectures on the educational component are delivered in parallel with the consideration of issues for self-study. Lectures are delivered using video conferencing tools (Zoom) and illustrative material in the form of presentations posted on the Sikorsky-distance platform. Before each lecture, it is recommended to read the lecture materials, as well as the materials recommended for self-study.

№	Class description
1	***Theme 1. Fundamentals of material science for membrane design*** *The importance of the chemical structure of materials, physical properties of gases and liquids, and the interaction between gases/liquids and the membrane material. The structure-property relationship. Transport mechanisms in the context of material selection. Membrane manufacturing technologies.* *Express survey*
2	*Express survey on the previous lecture.* *Continuation of Theme 1– Performance and durability of membranes and the influence of starting materials on them. Membrane application and materials selection for their manufacture. Sustainability and environmental impact in the context of the development and processing of membrane materials. Principles of environmentally friendly membrane materials.*
3	*Express survey on the previous lecture.*

	Theme 2. Polymeric membrane materials *Polymeric membrane materials, their synthesis, features, application, advantages and disadvantages: polyvinylidene difluoride, polypropylene, polyamide, polysulfone, polyester sulfone, polyvinyl chloride, polyetherimide, polyvinyl alcohol, polylactic acid.*
4	*Express survey on the previous lecture.* *Continuation of Theme 2 – Polymeric membrane materials, their synthesis, features, application, advantages and disadvantages: cellulose-based materials, chitosan, alginates, polybutylene succinate. Technologies for polymeric membranes production with an emphasis on material properties. Modification of polymeric membranes. Strategies for chemical modification of the membrane surface. Chemical and physical modification.* *Execution of the reports.*
5	*Express survey on the previous lecture.* ***Theme 3. Ceramic membrane materials*** *Ceramic membrane materials, their synthesis, features, applications, advantages and disadvantages: metal oxides (aluminium, titanium, zirconium, silicon, etc.); zeolites; clays (kaolin, bentonite, fire clays, porcelain clays, etc.); silicon carbide; carbon-based materials (carbon nanotubes, graphenes, metal-organic frameworks (MOFs), MXenes, etc.).* *Execution of the reports*
6	*Express survey on the previous lecture.* *Continuation of Theme 3 – Additives and modifiers for ceramic membranes, their role, impact and application features. Technologies for the ceramic membrane production with a focus on material properties.* *Features of materials for the selective layer, their synthesis and technologies of application to the ceramic matrix. Technology of ceramic membranes 3D printing and specifics of selection and preparation of materials for their production.* *Modification of ceramic membranes. Strategies for chemical modification of the membrane surface. Chemical and physical modification* *Execution of the reports*
7	*Express survey on the previous lecture.* ***Theme 4. Composite membrane materials*** *Features of the combination of polymeric and inorganic materials for composite membranes. Imparting specific properties to composite membranes (mechanical strength, resistance to contamination, hydrophilicity, water permeability, antibacterial, etc.). Interfacial compatibility of composite membrane materials.* ***Theme 5. The modern materials and membranes based on them*** *Covalent organic frameworks (COFs). Biomimetic materials. Electroactive membranes. – Membranes based on ionic liquid. "Green" materials for membranes.*
8	***Module test***
9	***Credit*** *Students who have a low rating, as well as those who want to improve their grade, take a test in the form of an interview.*

Laboratory works

The purpose of laboratory work is to consolidate the theoretical knowledge gained in lectures and self-study and acquire practical skills in the educational component. To this end, laboratory classes provide a detailed examination of advanced materials for the creation of polymeric, ceramic, and composite membranes and study their properties. Students are also expected to work individually with literary sources while studying the educational component «Modern materials in membrane technologies». During laboratory classes, students will master the skills of synthesis and modification of polymer, cellulose, ceramic and composite membranes, including the synthesis of a selective layer. Laboratory work is carried out in the form of in-depth scientific research on a single topic, which is presented at the end of the semester in the form of a presentation and report.

Week	Theme	Description of planned work
1	Introductory class	Introductory safety briefing. Discussion of the labs available in the course and selection of a topic for in-depth research.
2	Synthesis of polymeric membranes, their characterisation and efficiency testing	Synthesis of polymeric membranes, determination of optimal synthesis parameters, study of their characteristics. Measurement of the transport capacity of the resulting membranes.
3	Synthesis of cellulose membranes, their characterisation and efficiency testing	Synthesis of cellulose membranes, determination of optimal synthesis parameters, study of their characteristics. Measurement of the transport capacity of the resulting membranes.
4	Modification of polymeric membranes	Modification of polymeric membranes by TiO_2 nanoparticles. Establishment of new surface properties. Characterisation of the obtained membranes and their testing.
5	Synthesis of ceramic membranes and their investigation	Formation of ceramic matrices by pressing and 3D printing. Determination of the phase composition and porosity of ceramic membranes after heat treatment. Determination of the permeability of the resulting membranes.
6	Synthesis of a selective layer of ceramic membranes and determination of their selectivity towards different pollutants	Development of a method for synthesis of a selective layer, determination of optimal synthesis parameters, and study of its characteristics. Determination of selectivity and parameters of membrane purification of aqueous solutions of different composition.
7	Synthesis of hydroxyapatite and its coating on the membrane surface	Study of methods for synthesis of hydroxyapatite and investigation the methods of its coating as a selective layer to the surface of membranes (spin-coating, dip-coating, etc.).
8	Using artificial intelligence to create, test and predict membrane performance	Using artificial intelligence to predict the behaviour of membranes during water treatment and to create new materials for membrane synthesis
9	Final class. Report defense on the work carried out	Defence of laboratory work and presentation of scientific results and report.

		Results summarisation. Students are informed of the number of points they have gained during the semester.

6. Self-studying of students/postgraduates

Self-study during the semester includes repetition of lecture material, preparation for tests, preparation for control measures on lecture material, preparation for the defence of laboratory works, as well as preparation for the credit. The recommended number of hours allocated for preparation for these types of work:

Type of self-studying	***Number of hours to prepare***
Preparation for classroom lessons: revision of lecture materials, preparation for tests	*6 hours*
Preparing for the defence and presentation of the laboratory report	*36 hours*
Performing homework test	*10 hours*
Preparing for module test	*4 hours*
Execution of the report	*4 hours*
Preparing for the final test	*6 hours*
Total	*66 hours*

Policy and control

7. The policy of the educational component

In the normal operation of the university, lectures are held in classrooms. In the blended mode, lectures are held via the Sikorsky Distance Learning Platform, and laboratory work is conducted in laboratories. In the distance mode, all classes are held through the Sikorsky distance learning platform. Attendance at lectures and laboratory work is mandatory.

Before the start of the next topic, the lecturer sends lecture material using interactive tools to familiarise students and enable them to prepare for the class.

Rules for the defence of the homework test:

1. *Only students who have correctly completed and submitted a written homework test in accordance with the requirements are allowed to defend their work*
2. *The defence takes place according to the schedule specified in clause 5 for individual tasks.*
3. *After the assignment is checked by the teacher and defended by the student, the overall grade is given, and the work is considered defended.*

Rules for awarding reward and penalty points:

1. *For each week of delay in submitting the work, 1 penalty point is awarded (but not more than 5 points).*
2. *From 1 to 5 incentive points are awarded for the modernisation of works.*
3. *For completing tasks to improve didactic materials on the educational component, from 1 to 10 incentive points are awarded.*

Policy of deadlines and retakes: determined by paragraph 8 of the Regulations on current, calendar and semester control of learning outcomes at Igor Sikorsky Kyiv Polytechnic Institute.

Policy on academic integrity: determined by the policy of academic integrity and other provisions of the University Honour Code https://kpi.ua/files/honorcode.pdf, which establishes general moral principles, rules of ethical behaviour of persons and provides for a policy of academic integrity for persons

working and studying at the university, which they should be guided in their activities, including when studying and passing control measures in the EC "Modern materials in membrane technologies".

During using digital means of communication with the teacher (mobile communication, e-mail, correspondence in telegram chats), it is necessary to adhere to generally accepted ethical norms to be polite and limit communication to the teacher's working hours.

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

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

1. *Current control: questioning during lectures, laboratory work, module test, etc.*
2. *Calendar control: carried out twice a semester as a monitoring of the current state of fulfilment of the Syllabus requirements.*
3. *Semester control: oral test.*

Rating system for assessing learning outcomes

The student's rating in the educational component is calculated based on a 100-point scale. The rating (during the semester) consists of the points that the student receives for:

1) *surveys during lectures;*
2) *work in lab classes;*
3) *homework test;*
4) *passing the module test;*
5) *preparation of the report.*

1. Lectures:
*The weighting score is **14 points** (7 express surveys with 2 points each):*
"excellent", correct answers (95-100%) – 1.9-2 points;
"good" – 75-94% of correct answers – 1.6-1.8 points;
"satisfactory" – 60-74% of correct answers – 1.3-1.5 points;
"unsatisfactory" – no correct answers (less than 60%) – 0 points.

2. Laboratory works:
*The weighting score is **30 points** (conducting research within the framework of laboratory classes and presenting a report in the form of a presentation):*
"excellent", creative disclosure of the issue, fluency in the material (95-100%) – 28.5-30 points;
"good", in-depth disclosure of the issue (75-94%) – 22.5-28 points;
"satisfactory", incomplete coverage of the topic (60-74%) – 18-22 point;
"unsatisfactory" (less than 60%) – 0 points.

3. Homework test:
*The weighting score is **20 points**:*
"excellent", creative disclosure of the issue, fluency in the material (95-100%) – 19-20 points;
"good", in-depth coverage of the issue (75-94%) – 14.8-18 points;
"satisfactory" (60-74%) – 12-14 point;
"unsatisfactory" (less than 60%) – 0 points.

4. Module test
*The weighting score for the module test is **20 points**:*
"excellent", creative disclosure of the issue, fluency in the material (95-100%) – 19-20 points;
"good", in-depth coverage of the issue (75-94%) – 14.8-18 points;
"satisfactory" (60-74%) – 12-14 point;
"unsatisfactory" (less than 60%) – 0 points.
The assessment is carried out in the form of testing (40 test questions with 0.5 points each, time limit - 90 minutes).

5. Report

*The weighting score for the report is **16 points**:*
"excellent", complete answer (95-100% of the required information), disclosed creatively, using scientific approaches – 15.2-16 points;
"good", a sufficiently complete answer (75-94% of the required information), or a complete answer with minor inaccuracies - 12÷15 points;
"satisfactory", incomplete answer (60-74% of the required information) and minor errors – 10-11 points;
"unsatisfactory", an unsatisfactory answer (less than 60%) – 0 points.

The condition for obtaining a positive grade in the calendar control is the completion of all the work planned for this time. At the first calendar control (week 8), student will receive 'attestation' if his or her current rating is at least 0.5·24 = 12 points. At the second calendar control (14th week), a student will receive "attestation" if his or her current rating is at least 0.5·54 = 27 points and the home work test is passed.
To receive test for a course with an automatic grade, the student must have a grade of at least 60 points, pass homework test, complete all laboratory works, and prepare a report on laboratory works. The rating points obtained during the semester are translated into the corresponding grade according to the table below.

Table of correspondence between rating points and grades on the university scale:

Number of points	***Grade***
100-95	*Excellent*
94-85	*Very good*
84-75	*Good*
74-65	*Satisfactory*
64-60	*Enough*
Less than 60	*Unsatisfactory*
The conditions for admission are not met	*Not allowed*

Students who have less than 60 points at the end of the semester, as well as those who want to improve their grade, take an oral test. A prerequisite for admission to the test is a positive grade for the homework test, completion of all laboratory work and submission of the laboratory report. The task of the test consists of two questions (theoretical and practical on the topic of laboratory work) of the work programme from the list provided in the methodological recommendations for mastering the credit module.
The theoretical question of the test is worth 40 points according to the grading system:
"excellent", complete answer (95-100% of the required information) – 38-40 points;
"good", a sufficiently complete answer (75-94% of the required information or minor inaccuracies) - 30÷37 points;
"satisfactory", incomplete answer (60-74% of the required information and some errors) – 24÷29 points;
"unsatisfactory", unsatisfactory answer (less than 60%) – 0 points.
The practical question of the test is worth 40 points according to the grading system:
"excellent", complete answer (95-100% of the required information) – 38-40 points;
"good", a sufficiently complete answer (75-94% of the required information or minor inaccuracies) - 30÷37 points;
"satisfactory", incomplete answer (60-74% of the required information and some errors) – 24÷29 points;
"unsatisfactory", unsatisfactory answer (less than 60%) – 0 points.
The points obtained in the test are summed up with the points obtained in the homework test and converted into the appropriate grade according to the table above.

9. Additional information on the educational component

The requirements for the design of the homework test and the list of questions for the credit test are given in the Google Classroom "Modern materials in membrane technologies"(Sikorsky-distance platform).
Crediting of certain results obtained in non-formal education is carried out in accordance with the Regulations on the recognition of learning outcomes in non-formal/informal education at Igor Sikorsky Kyiv Polytechnic Institute https://osvita.kpi.ua/node/179.

Syllabus of the educational component:

Compiled by

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Approved *by Department of Inorganic Substances Technology, Water Treatment and General Chemical Technology (№ 26 of 30.06.2025)*

Agreed *by Methodological Commission of Faculty of Chemical Technology (№ 10 of 26.06.2025)*