Lodz University of Technology

Heterophasic Reactors

Course description

Basic information

Study programme Industrial Process Engineering **Speciality/path** - **Organizational unit** Faculty of Process and Environmental Engineering **Study level** second-cycle programme (magister inżynier) **Study mode** full-time studies **Education profile** general academic	**Didactic cycle** 2026/27 **Course code** **Language of instruction** polish **Obligatory** Optional **Block** Directional subjects **Course related to scientific research** Yes

Course coordinator	Mariola Błaszczyk
Course instructor(s)	Mariola Błaszczyk, Radosław Ślęzak

Period	**Form of verification**	**Total ECTS points**
Semester 2	Graded assignment **Classes and hours** • Lecture: 30 • Tutorials: 20 • Project work: 20	5

Prerequisites

Basic knowledge of engineering, microbiology, physical chemistry, fluid mechanics, and heat and mass transfer.

Learning outcomes

Code	Programme outcomes	Detailed outcomes indicators
2IPP2	Possesses advanced, including specialised, knowledge in material and energy balances, fluid mechanics, momentum transfer, heat and mass transfer, reaction kinetics, separation processes, process dynamics and control, equipment design, and product manufacturing technologies; analyses and evaluates the main development trends in chemical and biochemical engineering.	2IPP2.1 Develops and analyses material and energy balances for various chemical and biochemical engineering processes, applying advanced knowledge of fluid mechanics, momentum transfer, and heat and mass transport. 2IPP2.2 Designs and optimises reactors and process equipment, considering process dynamics and effective control of chemical and biochemical reactions.
2IPP4	Formulates and tests research tasks related to modelling and design; integrates knowledge from various areas of chemical engineering and allied disciplines; performs critical analysis and evaluation of results.	2IPP4.1 Defines a research problem in the field of chemical engineering, applying an interdisciplinary approach.

Course contents

Design and analysis of heterogeneous reactors, classification and operating principles, gas–liquid and gas–solid reactors, kinetics and balances in multiphase processes, reactor design and performance assessment in modern industrial technologies.

Complementary information

Contents - detailed selection

No.	Contents - detailed selection	Class type
1.	Within the lecture part, the following topics are covered. 1. Heterogeneous reactors – introduction: definition of heterogeneous processes, classification of reactors with respect to the number and physical state of phases and the mode of phase contact. Importance of heterogeneous reactors in chemical and process engineering. 2. Homogeneous reactors (revision and systematization of knowledge): review of basic ideal reactor models, mass and energy balance equations, and their role as a reference for the analysis of heterogeneous reactors. 3. Types of heterogeneous reactors: classification of gas–liquid, gas–solid, liquid–solid and multiphase reactors, including principles of operation and areas of application of individual reactor types. 4. Catalytic reactors: fundamentals of catalytic reactions, the role of the catalyst in heterogeneous processes, classification of catalytic reactors and their industrial applications. 5. Catalysts in heterogeneous processes: concept of heterogeneous catalysis, mechanism of catalyst action, types of catalysts used in heterogeneous processes, methods of catalyst preparation, basic catalyst parameters (activity, selectivity and stability) and methods of catalyst characterization. 6. Adsorption and kinetics of catalytic reactions: adsorption and desorption phenomena, kinetic models of catalytic reactions and the influence of process parameters on the reaction rate. 7. Internal diffusion in catalytic processes: mass transport in the porous structure of the catalyst, diffusion resistances and their effect on reaction rate and catalyst effectiveness. 8. External diffusion in catalytic processes: mass transfer between the fluid phase (gas or liquid) and the catalyst surface, mass transfer resistances and their influence on the course of the reaction. 9. Balance equations for catalytic reactors: mass and energy balance equations for catalytic reactors, mathematical models of reactor operation and fundamentals of reactor design and scale-up. 10. Catalyst deactivation: mechanisms of catalyst deactivation, its impact on reactor performance and basic methods of catalyst regeneration and mitigation of deactivation. 11. Non-catalytic reactions: characteristics of heterogeneous non-catalytic reactions, reaction kinetics and models describing the course of these processes. 12. Liquid–liquid heterogeneous reactors: principles of contacting liquid phases, reaction kinetics in liquid–liquid systems, balance equations and fundamentals of liquid–liquid reactor design. 13. Fluidized-bed reactors: fundamentals of fluidization, characteristics of fluidized-bed reactors, bed hydrodynamics and industrial applications. 14. Three-phase reactors and other types of heterogeneous reactors: characteristics of gas–liquid–solid reactors, membrane reactors, biochemical reactors and microreactors. 15. Safety of reactor processes: identification of hazards in heterogeneous processes and basic principles of safe design and operation of chemical reactors.	Lecture
2.	The tutorials have a computational and problem-solving character and involve individual and group work on numerical problems related to the analysis of processes occurring in heterogeneous reactors. They cover issues concerning the coupling of chemical reaction kinetics with mass transfer in heterogeneous systems, with particular emphasis on catalytic processes. The problems addressed focus on the assessment of the influence of internal and external diffusion resistances on the reaction rate, the interpretation of dimensionless criteria used in the analysis of heterogeneous processes, and the determination of parameters characterizing catalyst effectiveness. The tutorials also include the analysis of mass transfer in the porous structure of catalysts, the selection of geometric parameters of catalyst particles, and the evaluation of their impact on the course of the reaction process and the hydrodynamic conditions of the bed. Special emphasis is placed on the engineering interpretation of calculation results, the identification of dominant process resistances, and their significance in the design and operation of heterogeneous reactors.	Tutorials
3.	Design of a heterogeneous reactor for CO_2 adsorption with a chemical reaction. Selection of process equipment and instrumentation for process monitoring and control.	Project work

Teaching methods and techniques, passing conditions

Class type	Teaching methods and techniques	Passing conditions
Lecture	Lecture	A positive grade in the final written assessment. Achievement of at least 60% of the total points.
Tutorials	Practice method	The condition for passing the tutorials is the independent solution of a computational and design-oriented problem in the field of heterogeneous reactor engineering, including quantitative analysis and an engineering evaluation of the obtained results in the context of the design and operation of heterogeneous reactors.
Project work	Project execution	Proper preparation and defense of the project (presentation).

Examination methods, weighed grades

Class type	Examination methods and weighed grades
Lecture	Written assignment: 45%
Tutorials	Practical test: 25%
Project work	Design Project: 30%

Verification of learning outcomes

Detailed outcome indicators	Verification criteria	Assesment tool (class type)
2IPP2.1	1) Written assessment A positive grade is awarded if the student: • correctly formulates and analyzes material and energy balances for heterogeneous reactors, taking into account chemical reactions as well as mass and heat transfer phenomena; • identifies and interprets the influence of process parameters on the course and efficiency of heterogeneous processes; • applies and interprets dimensionless numbers and criteria used in the analysis of reactor processes. 2) Computational exercises (tutorials) A positive grade is awarded if the student: • performs correct quantitative calculations related to the analysis of processes occurring in heterogeneous reactors, in particular with respect to the coupling of reaction kinetics and mass transfer; • analyzes the effect of internal and external diffusion resistances on reaction rate and process balances; • interprets the obtained results in the context of transport limitations and their significance for reactor performance. 3) Project and project presentation A positive grade is awarded if the student: • develops a concept of a heterogeneous reactor or heterogeneous process based on the analysis of material and energy balances; • selects and justifies process parameters taking into account mass and heat transfer phenomena; • presents and defends the adopted design solutions, demonstrating the ability to perform an engineering interpretation of the calculation results.	Written assignment (Lecture), Design Project (Project work), Practical test (Tutorials)

Detailed outcome indicators	Verification criteria	Assesment tool (class type)
2IPP2.2	1) Written assessment (midterm / final examination) A positive grade is awarded if the student: • demonstrates knowledge of the basic principles of designing and selecting heterogeneous reactors and process equipment; • identifies parameters influencing the course, stability, and dynamics of reaction processes; • understands the role of process control and regulation in ensuring the proper course of chemical and biochemical reactions. 2) Computational exercises (tutorials) A positive grade is awarded if the student: • analyzes the impact of changes in process parameters on the operation of heterogeneous reactors; • interprets calculation results in the context of process efficiency and stability; • formulates general conclusions regarding the optimization of reaction conditions. 3) Project and project presentation A positive grade is awarded if the student: • develops a concept of a heterogeneous reactor or process equipment appropriate for a given process; • proposes and justifies general design assumptions, including the selection of reactor type and basic operating parameters; • relates the adopted solutions to the requirements for stable process operation and controllability; • presents and defends the project, demonstrating an understanding of the engineering aspects of heterogeneous reactor design.	Written assignment (Lecture), Design Project (Project work), Practical test (Tutorials)
2IPP4.1	1) Written assessment (midterm / final examination) A positive grade is awarded if the student: • identifies and formulates research problems related to processes occurring in heterogeneous reactors; • indicates key chemical, transport, and hydrodynamic phenomena relevant to their description and analysis. 2) Computational / problem-solving exercises (tutorials) A positive grade is awarded if the student: • analyzes engineering and research problems related to heterogeneous reactors, identifying variables, parameters, and process constraints; • interprets the results of analyses in order to identify directions for further research. 3) Project and project presentation A positive grade is awarded if the student: • defines a research problem related to the analysis or design of a heterogeneous reactor; • specifies the objective and scope of the problem, integrating chemical, physical, and engineering aspects; • justifies the formulated research problem using an interdisciplinary approach.	Written assignment (Lecture), Design Project (Project work), Practical test (Tutorials)

Literature

Compulsory reading

1. O. Levenspiel, Chemical Reaction Engineering, Wiley, N.Y., 1999.
2. A. Burghardt, G. Bartelmus, Inżynieria reaktorów chemicznych. Tom II Reaktory dla układów heterogenicznych. PWN, Warszawa, 2001.
3. S. Ledakowicz, Wielofazowe reaktory chemiczne, WPŁ, Łódź, 1994.
4. M. Palica, M. Płaczek, J. Thullie, S. Witczak, Reaktory chemiczne heterogeniczne, OW, Opole, 2012

Other reference materials

1. L.D. Schmidt, The Engineering of Chemical Reactions, Oxford University Press, 2005.
2. L.K. Doraiswamy, M.M. Sharma, Heterogeneous reactions, vol. I, II, Wiley, N.Y., 1984.
3. A. Chacuk, A. Cieślak, S. Ledakowicz, Zbiór zadań z inżynierii procesów reaktorowych, WPŁ, Łódź, 1988.

Research and publications

M. Błaszczyk, J. Sęk, Ł. Przybysz, Modeling of flow resistance and concentration changes during the pressure transport of emulsion through porous media, Chemical Engineering Research and Design, 127, 10-21, 2017, DOI:10.1016/j.cherd.2017.08.018
M. Błaszczyk, J. Sęk, Ł. Przybysz, Modeling and experimental data of the flow of highly concentrated emulsions in porous media, Engineering Science and Technology, an International Journal, 23, 6, 1444 – 1454, 2020, DOI:10.1016/j.jestch.2020.07.003
M. Błaszczyk, J. Sęk, Ł. Przybysz, The combined diffusion and adsorption concept for prediction of nanoparticles transport through dermal layers based on experiments in membranes, International Journal of Molecular Sciences, 23, 12, 2022 Article number 6419, DOI:10.3390/ijms23126419
M. Błaszczyk, J. Sęk, Ł. The new attempt at modeling of the three-dimensional geometry of the epidermal skin layer and the diffusion processes of nanomolecular drug carriers in such structures, Molecules, 28, 1, 2023 Article number 205, DOI:10.3390/molecules28010205
M. Błaszczyk, Ł. Przybysz, A. Budzyń. The Influence of the Variable Wettability Characteristics of Layers on the Transport of Nanoparticles in the Context of Drug Delivery in Skin Structures. INTERNATIONAL JOURNAL OF MOLECULAR SCIENCES, ISSN: 1422-0067, vol. 25, no. 9, rok 2024, str. 1-15. 10.3390/ijms25094665

Student workload

Activity type	**Average number of hours* needed to complete an activity**
Lecture	30
Tutorials	20
Project work	20
pk: Feedback exchange session	5
pk: Project presentation session	5
Participation in written or practical forms of verification	4
Participation in academic consultations	4
Literature analysis	5
Preparation for test	15

Preparation for tutorials	10
Preparation of the project	10
Total student workload	**No. of hours** 128
Workload involving teacher	**No. of hours** 80
Total ECTS points	**ECTS** 5

* activity hour equals to 45 minutes

Directional learning outcomes

Code	Content
2IPP2.1	Develops and analyses material and energy balances for various chemical and biochemical engineering processes, applying advanced knowledge of fluid mechanics, momentum transfer, and heat and mass transport.
2IPP2.2	Designs and optimises reactors and process equipment, considering process dynamics and effective control of chemical and biochemical reactions.
2IPP4.1	Defines a research problem in the field of chemical engineering, applying an interdisciplinary approach.