Lodz University of Technology

# Multiphase Flows

Course description

## Basic information

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

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|---|---|
| **Course coordinator** | Piotr Owczarz |
| **Course instructor(s)** | Piotr Owczarz, Remigiusz Modrzewski, Jarosław Sowiński, Anna Rył, Mariola Błaszczyk, Bertrand Jóźwiak |

| **Period** | **Form of verification** | **Total ECTS points** |
|---|---|---|
| Semester 6 | Graded assignment<br><br>**Classes and hours**<br>• Lecture: 25<br>• Seminar: 15<br>• Laboratory classes: 20 | 4 |

## Prerequisites

Knowledge of Mathematics I, Physics I, Fluid Mechanics, and Introduction to Mathematical Analysis, including the fundamentals of differential calculus and the ability to solve systems of differential equations.

## Learning outcomes

| Code | Programme outcomes | Detailed outcomes indicators |
|---|---|---|
| 1IPP2 | Has knowledge of key chemical and process engineering processes, including: (1) momentum, heat and mass exchange mechanisms and their application in unit operations and process apparatus; (2) principles of mass, energy and momentum balancing in process engineering processes; (3) product separation, separation and purification processes; (4) fundamentals of chemical and biochemical reaction engineering. | 1IPP2.1 Explain the mechanisms of momentum, heat and mass exchange and describe their role in basic unit operations and process apparatus. |
| 1IPP4 | Applies analytical and critical thinking to identify, formulate, and solve complex and atypical engineering problems related to industrial processes and process installations, selecting appropriate computational, technological, and organisational methods. | 1IPP4.2 Selects and applies appropriate computational methods and engineering tools (e.g. balances, basic transport models, flow analyses) to assess process performance. |

## Course contents

Fundamentals of multiphase flows, including gas–liquid, liquid–solid, and gas–solid systems, with an emphasis on hydrodynamic and transport phenomena. The course introduces modelling, analysis, and selection of process parameters in process engineering installations.

## Complementary information

**Contents - detailed selection**

| No. | Contents - detailed selection | Class type |
|---|---|---|
| 1. | Nature and areas of occurrence of multiphase flows in the processing of materials and biomaterials. Fundamental properties of the dispersed phase. | Lecture |
| 2. | Sizes and shapes of particles, droplets, and bubbles. Determination of viscosity and interfacial contact area in multiphase systems. | Lecture |
| 3. | Flow of liquid–solid particle mixtures. Fluid–solid particle systems. Fundamentals of sedimentation theory. | Lecture |
| 4. | Methods for the separation of fluid–solid systems: filtration, centrifugation, and dust removal (dedusting). | Lecture |
| 5. | Liquid–gas systems. Models of gas bubble formation and growth, flow regimes, phase fractions and flow resistance in liquid–gas mixtures, and the theory of gas sparging (bubbling). | Lecture |

| No. | Contents - detailed selection | Class type |
|---|---|---|
| 6. | Fluidization processes and pneumatic conveying. | Lecture |
| 7. | Liquid–liquid systems. Methods of emulsion generation and stability of emulsions. Flow of liquid–liquid and liquid–gas systems in microchannels, including flow regimes and mechanisms of droplet and bubble formation. | Lecture |
| 8. | Investigation of the shape and size of gas bubbles formed in different liquids, as well as the study of gas bubble flow velocities. | Laboratory classes |
| 9. | Investigation of phase fractions in liquid–gas and liquid–solid particle mixtures, determination of sedimentation velocities of dispersed systems, and phase separation kinetics using turbidimetry. | Laboratory classes |
| 10. | Fluidized bed dynamics and pneumatic conveying. | Laboratory classes |
| 11. | Analysis of industrial processes combined with the identification of multiphase flow regimes occurring within them. Preparation of a presentation related to an industrial process and the methodology for determining process parameters. | Seminar |

**Teaching methods and techniques, passing conditions**

| Class type | Teaching methods and techniques | Passing conditions |
|---|---|---|
| Lecture | Lecture | Written examination based on the lecture. The requirement for passing is obtaining a positive grade, i.e. achieving at least 60% of the total available points. |
| Seminar | Multimedia presentation, Discussion, Peer assessment, Work with source text | Obtaining a positive grade requires:<br>• Delivery of a multimedia presentation / seminar paper on an assigned topic, which constitutes 60% of the seminar grade;<br>• Active participation in the discussion of presentations delivered by other students, as assessed by the academic instructor, which constitutes 40% of the seminar grade. |
| Laboratory classes | Work with source text, Laboratory/computer-based exercises | The requirement for passing the course is obtaining a positive grade from:<br>• Oral assessments for all laboratory exercises performed. The averaged grade from the oral tests constitutes 20% of the final course grade (66% of the laboratory grade).<br>• A positive grade for a substantive laboratory report prepared in laboratory groups, which constitutes 10% of the final course grade (34% of the laboratory grade). The instructor may differentiate the final report grades by taking into account ongoing observation of the student’s performance during laboratory classes, including, among others, active participation in laboratory work and contribution to the processing and analysis of results. |

**Examination methods, weighed grades**

| Class type | Examination methods and weighed grades |
|---|---|
| Lecture | Written assignment: 40% |
| Seminar | Multimedia presentation: 30% |
| Laboratory classes | Report: 10%<br>Speaking assignment: 20% |

**Verification of learning outcomes**

| Detailed outcome indicators | Verification criteria | Assesment tool (class type) |
|---|---|---|
| 1IPP2.1 | Obtaining a positive grade requires that the student is able to:<br>• define fundamental quantities and concepts of multiphase flow used in chemical and biochemical engineering, and discuss methods for determining phase fractions and flow resistances in two-phase and multiphase mixtures;<br>• analyze the mechanisms of multiphase flows in macro- and microchannels;<br>• characterize and compare different aeration techniques, and perform measurements of basic multiphase flow parameters using appropriate equipment, including bubble shape, size, and velocity in a liquid layer, phase fractions and flow resistance of two-phase mixtures, sedimentation velocity, and aeration kinetics in liquid–gas systems;<br>• characterize and compare fluidized beds, calculate parameters of fluidization and pneumatic conveying processes, conduct experiments related to fluidization and pneumatic transport, and analyze the obtained results;<br>• analyze industrial processes with respect to the occurrence of multiphase flows. | Written assignment (Lecture), Report (Laboratory classes), Multimedia presentation (Seminar) |
| 1IPP4.2 | Processing and analysis of experimental results<br>A positive grade is awarded when the student:<br>• is able to work effectively in a group and, through joint discussion, interprets the results with respect to the aim and hypothesis, indicating their significance;<br>• actively participates in laboratory classes as well as in the processing of the obtained results and the preparation of the report, as assessed on the basis of the instructor’s observation. | Speaking assignment (Laboratory classes), Report (Laboratory classes) |

## Literature

**Compulsory reading**


1. J. Palarski, Hydrotransport, WNT, Warsaw 1982
2. M. Dziubiński, J. Prywer, Mechanika płynów dwufazowych, WNT, Warszawa 2010
3. K. Rup, Mechanika płynów w środowisku naturalnym, Wyd. Politechniki Krakowskiej, Kraków 2003
4. M. Dziubiński, Hydrodynamika przepływu mieszanin dwufazowych ciecz-gaz, Wyd. PŁ, Łódź 2005
5. C.E. Brennen, Fundamentals of multiphase flow, Cambridge University Press, Cambridge


**Other reference materials**


1. De Kee D., Chhabra R.P., Transport processes in bubble, drops and particles, Taylor&Francis, London 2002
2. Faghri A., Zhang Y., Transport phenomena in multiphase system, Elsevier, Amsterdam 2006


## Research and publications


1. Rył, A., & Owczarz, P. (2021). Thermoinduced aggegation of chitosan systems in perikinetic and orthokinetic regimes. Carbohydrate polymers, 255, 117377.
2. Rył, A., & Owczarz, P. (2020). Injectability of thermosensitive, low-concentrated chitosan colloids as flow phenomenon through the capillary under high shear rate conditions. Polymers, 12(10), 2260.


## Student workload

| Activity type | Average number of hours* needed to complete an activity |
|---|---|

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|---|---|
| Lecture | 25 |
| Seminar | 15 |
| Laboratory classes | 20 |
| Preparation of the paper | 15 |
| Participation in written or practical forms of verification | 2 |
| Literature analysis | 15 |
| Preparation for the laboratory | 10 |
| Preparation for test | 10 |
| Participation in academic consultations | 5 |
| | |
| **Total student workload** | **No. of hours**<br>117 |
| **Workload involving teacher** | **No. of hours**<br>60 |
| **Total ECTS points** | **ECTS**<br>4 |

* activity hour equals to 45 minutes

## Directional learning outcomes

| Code | Content |
|---|---|
| 1IPP2.1 | Explain the mechanisms of momentum, heat and mass exchange and describe their role in basic unit operations and process apparatus. |
| 1IPP4.2 | Selects and applies appropriate computational methods and engineering tools (e.g. balances, basic transport models, flow analyses) to assess process performance. |