POZNAN UNIVERSITY OF TECHNOLOGY
EUROPEAN CREDIT TRANSFER AND ACCUMULATION SYSTEM (ECTS)

# COURSE DESCRIPTION CARD - SYLLABUS

Course name
TURBULENT FLOWS IN SCIENCE AND TECHNOLOGY [S5ISGIE>PTNT]

## Course

Proposed by Discipline
–

Year/Semester
3/5

Level of study
Doctoral School

Course offered in
English

Form of study
full-time

Requirements
elective

## Number of hours

Lecture
8

Laboratory classes
0

Other
0

Tutorials
0

Projects/seminars
0

## Number of credit points

2,00

## Coordinators

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## Lecturers

prof. dr hab. inż. Ewa Tuliszka-Sznitko
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## Prerequisites

Basic knowledge of mathematics, including partial and ordinary differential equations. Knowledge of basic laws of mechanics, fluid mechanics, and heat transfer.

## Course objective

The aim of lecture is to familiarize students with the fundamental issues related to turbulence and to present this problem from a scientific and technological perspective. The lecture shows how progress in turbulence research influences the development of technology. The main goal of turbulence research is to accurately understand and describe the chaotic motions of fluids (liquids and gases). This helps us to improve flight safety, save fuel in transportation, improve flow machines design, and predict weather and climate changes. The study of turbulence brings together engineers, physicists and computational scientists.

## Course-related learning outcomes

Knowledge (W):
A doctoral student knows and understands:
P8S_WG/SzD_W01
global achievements, covering theoretical foundations as well as general and selected specific issues that are relevant to scientific disciplines studies at the Doctoral School, to the extent that enables revision of

existing paradigms

P8S_WG/SzD_W02
key development trends of disciplines of science in which education at the Doctoral School takes place

P8S_WG/SzD_W03
scientific research methodology in disciplines represented at the Doctoral School,

P8S_WG/SzD_W04
principles of disseminating results of scientific activity, also in an open access mode

P8S_WK/SzD _W05
fundamental dilemmas of the contemporary civilization,

P8S_WK/SzD _W06
economic, legal, ethical and other vital conditions related to scientific activity,

P8S_WK/SzD _W07
basic principles of knowledge transfer to the economic and social sphere as well as those of commercialization of results of scientific activities and know-how related to these results.

Skills (U)
A doctoral student can:
P8S_UW/SzD_U01
use knowledge from different branches of science to creatively identify, formulate and innovatively solve complex problems or to perform research tasks such as:
- define the aim and subject of scientific research, form a research hypothesis,
- develop research methods, techniques and tools and use them creatively,
- draw conclusions on the basis of research results,

P8S_UW/SzD_U02
critically analyze and assess scientific research results, work of experts and other creative activities together with their contribution into knowledge development,

P8S_UW/SzD_U03
transfer the results of scientific activity to the economic and social sphere,

P8S_UK/SzD_U04
communicate on specialist issues on the level that allows active participation in the international scientific community,

P8S_UK/SzD_U05
share results of scientific activity also in a popular form,

P8S_UO/SzD_U09
plan and implement individual and team research projects, also in the international community,

SOCIAL COMPETENCIES (K)
A doctoral student is ready to:
P8S_KK/SzD_K01
critically assess achievements within a given scientific discipline,

P8S_KK/SzD_K02
critically evaluate their own contribution to development of a given scientific discipline,

P8S_KK/SzD_K03
acknowledge the importance of knowledge in solving cognitive and practical problems,

P8S_KO/SzD_K04
fulfilling the social obligations of researchers and creators,

P8S_KO/SzD_K05
initiate actions in the public interests,

P8S_KR/SzD_K07
maintain and develop the ethos of research and creative communities, including:
- conducting independent scientific activity,
- respecting the principle of public ownership of the results of scientific activities, including the principles of intellectual property protection.

## Methods for verifying learning outcomes and assessment criteria

Learning outcomes presented above are verified as follows:

1) The evaluation is based on a written report prepared by doctoral candidates after completing the lecture course. Students can summarize all the presented material or focus on a selected topic and expand on it.
2) The evaluation also relies on student activity during the lecture (participation in discussions, questions), as well as on attendance.

## Programme content

1. Turbulence in technology
2. The equations of motion
3. The linear instability theory and the flow examples
3a. Kelvin–Helmholtz instability
3b. Tollmien–Schlichting instability
3c. Rayleigh stability criterion
4. Inflectional instability – cross-flow instability
4a. Cross-flow instability at the swept wing
4b. Contamination of the swept wing attachment line
4c. Suction system at the swept wing
4d. Kerman, Bödewadt and Ekman flows
4e. Rayleigh-Bernard convection (non-isothermal flow)
4f. Instability of the supersonic flow around rotating con (compressible flow)
5. The characteristics of turbulence
5a. Phenomenology and statistical description of turbulence
5b. Kolmogorov law
5c. Wall law
5d. Reynolds Averaged Navier-Stokes Equations (RANS)
5e. Direct Numerical Simulation (DNS)
5f. Large Eddy Simulation (LES)
6. Commentary on Reynolds equations
6a. Turbulence modelling for CFD (k, eps), (omega, eps)
6b. Experimental methods – flow visualization, Particle Image Velocimetry
7. Turbulent flows (examples)
7a. Channel flow
7b. Pipe flow
7c. Taylor-Couette flow (supercritical and subcritical transitions)
7d. Kepler flow
7e. Turbulence of atmosphere and its importance for aviation

## Course topics

Lecture 1
Turbulence in technology. Equations of motions. Linear instability theory (Kelvin-Helmholtz instability, Tollmien-Schlichting instability). Rayleigh stability criterion. Inflectional instability – cross-flow instability. Cross-flow instability at the swept wing. Instability at the wing attachment line (contamination). Suction system at the swept wing.

Lecture 2
The Kerman, Bödewadt and Ekman flows. Instability of the supersonic flow around rotating con (compressible flow, shock waves). Rayleigh-Bernard convection (non-isothermal flow). The characteristics of turbulence (phenomenology). Kolmogorov law. Reynolds Averaged Navier-Stokes Equations (RANS). Direct Numerical Simulation (DNS). Large Eddy Simulation (LES).

Lecture 3
Commentary on Reynolds equations. Turbulence modelling for CFD (k, eps), (omega, eps). Experimental methods – flow visualization, Particle Image Velocimetry (PIV). Turbulent flow examples: channel flow, pipe flow (puffs, slugs), flows through fluid-flow machines.

Lecture 4
Taylor-Couette flow (supercritical and subcritical transition to turbulence). Turbulent spots, interpenetrating spirals. How turbulence becomes sustained? Kepler flows. Turbulence of atmosphere and its importance for aviation.

## Teaching methods

Multimedia presentation.

## Bibliography

Basic:
Lesieur M., 2008, Turbulence in Fluids, Springer
Wilcox D.C., 2006, Turbulence modelling for SFD, Birningham Press, Inc., San diego, California
Tuliszka-Sznitko E., 2011, Selected issues in the mechanics of rotating fluids (in polish), Poznan University of Technology Publishing House
Nieuwstadt F.T., Boersma B.J., Westeerweel J., 2016, Turbulence, Introduction to Theory and Applications of Turbulent Flows

Additional:
Avila M., Barkley D., Hof B., 2023, Transition to Turbulence in Pipe Flow, Annual Review of Fluid Mechanics, 55:575–602
Feldmann D., Borrero-Echeverry D., Burin M., Avila K., Avila K., 2023, Routes to turbulence in Taylor–Couette flow, Philosophical Transitions of the Royal Society A, A381:20220114, https://doi.org/10.1098/rsta.2022.0114
Reed H.L., Saric W.S., 1989, Stability of three-dimensional boundary layer, Annual Review of Fluid Mechanics, 21:235-284
Elsner W.J., 1987, Flow turbulence, (in polish), PWN

## Breakdown of average student's workload

| | Hours | ECTS |
|---|---|---|
| Total workload | 50 | 2,00 |
| Classes requiring direct contact with the teacher | 8 | 0,00 |
| Doctoral student's own work (literature studies, preparation for laboratory classes/tutorials, preparation for tests/exam, project preparation) | 42 | 2,00 |