THE DOCTORAL SCHOOL OF IPPT PAN

COURSE OFFERED IN THE DOCTORAL SCHOOL OF IPPT PAN

Name of the course	Polish	**Wstęp do modelowania zagadnień fizycznych**			
	English	**Introduction to Modelling of Multiphysics Problems**			
Type of the course	**Lectures (a specialised course)**				
Course coordinator	**Tomasz G. Zieliński, D.Sc., Ph.D., M.Sc., Eng., Professor at IPPT PAN**	Course teacher	**Tomasz G. Zieliński, D.Sc., Ph.D., M.Sc., Eng., Professor at IPPT PAN**		
Implementing unit	**ZTI**	Scientific discipline / disciplines	**Mechanical Engineering, Technical Physics**		
Level of education	**Doctoral studies**	Semester	**winter (or summer)**		
Language of the course	**English (or Polish; all lecture materials are in English only)**				
Type of assessment	**examination**	Number of hours in a semester	**32**	ECTS credits	**4**

Type of classes		Lecture	Auditory classes	Project classes	Laboratory	Seminar
Number of hours	in a week	**2**	**0**	**0**	**0**	**0**
	in a semester	**32**	**0**	**0**	**0**	**0**

1. Prerequisites
Knowledge of mathematics in the field of higher technical studies, including differential and integral calculus, ordinary differential equations, basics of partial differential equations and numerical methods. Fundamentals of general mechanics and physics, including waves.

2. Course objectives
The course is devoted to the mathematical modelling of fundamental problems in physics and engineering, with special attention to existing or possible multi-physics couplings. It consists of several introductory lectures on the relevant mathematical tools and numerical methods, as well as a series of lectures on single- and multi-physics problems, including derivation and implementation of their mathematical and numerical models. During the course, students should learn how to build such models from scratch, as well as modify or combine (couple) existing models. The objective is also to provide practical knowledge in using *COMSOL Multiphysics*, an advanced numerical environment designed to solve this type of problems.

3. Course content (separate for each type of classes)

Lecture

Theoretical lectures (main topics):

- Mathematical Preliminaries (basics of tensor calculus, integral theorems, etc.)
- Introduction to Partial Differential Equations
- Weighted Residual Methods
- Ritz and Galerkin Methods
- Introduction to Finite Element Method

- Heat Transfer Problems
- Fundamentals of Linear Elasticity
- Fundamentals of Piezoelectricity
- Ideal Flow Theory
- Basics of Aerodynamics
- Elementary Viscous Flow
- Waves in Fluids
- Basics of Multiscale Modelling
- Fundamentals of Acoustics
- Surface Acoustic Waves
- Acoustic Waves in Anisotropic Media and Piezoelectric Materials

Demonstration lectures on using *COMSOL Multiphysics*:

- Introduction to *COMSOL Multiphysics*
- Heat Transfer
- Model Implementation using *COMSOL PDE Interfaces*
- Elasticity and Thermoelasticity
- Piezoelectricity
- Computational Fluid Dynamics (CFD)
- Fluid-Structure Interaction (FSI)
- Acoustics and Vibroacoustics
- Porous Media Flow
- Piezoelectric and Surface Acoustic Waves

Laboratory
[not applicable]

4. Learning outcomes			
Number of the learning outcome	Learning outcomes description	Reference to the learning outcomes according to the 8th level of PRK	Learning outcomes verification methods*
	Knowledge		
1	The graduate acquires basic knowledge of the mathematical foundations of the finite element method.	P8S_WG	examination
2	The graduate acquires basic knowledge in the field of mathematical physics and finite element modelling of multi-physics problems.	P8S_WG	examination
3	The graduate knows how to transfer the acquired knowledge to the industrial sphere and disseminate the research results.	P8S_WK	assessment of activity during classes
	Skills		

1	The graduate is able to construct models of physical problems in their strong and weak formulations.	P8S_UW	examination
2	The graduate is able to implement and solve various single- and multiphysics problems using the finite element method.	P8S_UW	examination
3	The graduate is ready to apply the acquired knowledge of the finite element modelling of multi-physics and engineering problems in the field of his/her scientific research.	P8S_UW	assessment of activity during classes and examination
4	The graduate is able to transfer the acquired knowledge to the industrial environment and disseminate the research results.	P8S_UW	assessment of activity during classes
Social competences			
1	The graduate is ready to think and act in a creative and entrepreneurial way.	P8S_KO	assessment of activity during classes
2	The graduate is ready to critically evaluate the achievements of the represented scientific discipline, including his or her own contribution to the development of this discipline.	P8S_KK	assessment of activity during classes

*Allowed learning outcomes verification methods: exam; oral exam; written test; oral test; project evaluation; report evaluation; presentation evaluation; active participation during classes; homework; tests

5. Assessment criteria
assessment of activity during classes results of the examination

6. Literature
Primary references: [1] **T.G. Zieliński, "Introduction to Modelling of Multiphysics Problem – Lecture Notes"** **http://bluebox.ippt.pan.pl/~tzielins/index.php?im=1&id=lectures.html** Secondary references: [1] S.J. Farlow, "Partial Differential Equations for Scientists and Engineers" [2] J.N. Reddy, "An Introduction to the Finite Element Method" [3] D.J. Acheson, "Elementary Fluid Dynamics" [4] D.T. Blackstock, "Fundamentals of Physical Acoustics"

7. PhD student's workload necessary to achieve the learning outcomes**		
No.	Description	Number of hours
1	Hours of scheduled instruction given by the lecturer in the classroom	**32**
2	Hours of consultations with the lecturer, exams, tests, etc.	**16**

3	Amount of time devoted to the preparation for classes, preparation of presentations, reports, projects, homework	**25**
4	Amount of time devoted to the preparation for exams, test, assessments	**35**
	Total number of hours	**108**
	ECTS credits	**4**

** 1 ECTS = 25–30 hours of the PhD students work (2 ECTS ≈ 60 hours; 4 ECTS ≈ 110 hours, etc.)