COURSE OFFERED IN THE DOCTORAL SCHOOL

<table>
<tr><td rowspan="2">Code of the course</td><td rowspan="2">4606-ES-000BGHI-0375</td><td rowspan="2">Name of the course</td><td>Polish</td><td>Nanonauka i nowoczesne nanotechnologie w inżynierii mechanicznej</td></tr>
<tr><td>English</td><td>Nanoscience and Modern Nanotechnologies in Mechanical Engineering</td></tr>
<tr><td>Type of the course</td><td colspan="4">specialized</td></tr>
<tr><td>Course coordinator</td><td colspan="4">dr hab. Nataliya Kizilova</td></tr>
<tr><td>Implementing unit</td><td>MEiL</td><td>Scientific discipline / disciplines*</td><td colspan="2">Mechanical Engineering
Automation, electronics, electrical engineering and space technologies
Environmental engineering, mining and energy
Materials engineering</td></tr>
<tr><td>Level of education</td><td>doctoral studies</td><td>Semester</td><td colspan="2">winter</td></tr>
<tr><td>Language of the course</td><td colspan="4">English</td></tr>
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Type of assessment:	grade	Number of hours in a semester	26	ECTS credits	2
Minimum number of participants	10	Maximum number of participants	30	Available for students (BSc, MSc)	Yes/ ~~No~~

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<tr><td colspan="2">Type of classes</td><td>Lecture</td><td>Auditory classes</td><td>Project classes</td><td>Laboratory</td><td>Seminar</td></tr>
<tr><td rowspan="2">Number of hours</td><td>in a week</td><td>2</td><td></td><td>2</td><td></td><td></td></tr>
<tr><td>in a semester</td><td>18</td><td></td><td>8</td><td></td><td></td></tr>
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* does not apply to the Researcher's Workshop

1. Prerequisites

- Basic knowledge of mathematics,
- Basic knowledge of fluid and solid mechanics,
- Basic knowledge of computer science,
- Basic understanding of mechanical engineering problems.

2. Course objectives

1. To acquire advanced knowledge on general nanomechanics, nanophysics and modern nanotechnologies.
2. To understand modern trends and advantages in application of the nanotechnologies in different mechanical engineering problems from macro to micro/nano units.
3. To understand the differences in the physical laws (mass and heat transfer) and boundary conditions at the macro- and micro/nano scales.
4. To understand the differences in the physical/chemical properties of materials at the macro- and micro/nano scales.
5. To understand the possibilities of modern nanotechnology in manufacturing smart materials (structures, coatings).

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

Lectures

1. Fundamentals of mechanics. Solid mechanics and fluid mechanics. Transitions from classical continuum mechanics to the nanoscale matter with local effects, high surface-to-volume ratios, and unique physical properties.
2. Advanced structural nanocomposites and smart materials: properties, manufacturing and testing methods. Nanolattices and mechanical metamaterials.
3. Microfluidic and nanofluidic mechanics. Multipurpose nanofluid optimization.
4. Nanoscale thermal transport and energy systems. Phonon engineering and nanoscale thermal management.
5. Nano-tribology and molecular lubrication in interface engineering. triboelectric nanogenerators (tengs) for mechanical energy harvesting.

6. Biomimetic surface engineering and nanocoatings. Anti-icing, anti-fouling, drag-reduction and other unique properties.
7. Microelectromechanical systems (MEMS) and nanoelectromechanical systems (NEMS). Bio-MEMS and Bio-NENS. Carbon Nanotube (CNT) Actuators and Soft Robotics.
8. Intelligent nanomanufacturing. AI-driven atomically precise manufacturing. Sustainable and future engineering solutions

Project classes

1. Rheological models and problem formulations for micro/nanofluid flows in rough solid geometries: governing equations and boundary conditions.
2. Micro/nanofluid heat transfer optimization.
3. Friction and wear reduction via nanocoatings.
4. Lightweight nanocomposite structural design (aircrafts, drones).
5. Modeling of self-cleaning and anti-icing engineering surfaces.
6. Designing of MEMS/NEMS cantilever sensors.

4. Learning outcomes

	Learning outcomes description	Reference to the learning outcomes of the WUT DS	Learning outcomes verification methods*
	Knowledge		
W01	A PhD student gains a basic knowledge of mechanical properties and physical phenomena at micro/nano scales.	SD_W2, SD_W3	test
W02	Understands the differences between the governing equations and boundary conditions at the micro/nano and macro scales.	SD_W2, SD_W5	test
W03	Understands the latest trends and emerging models in nanosciences and modern nanotechnologies.	SD_W3, SD_W4	test
	Skills		
U01	Can select appropriate mathematical model and parameters for a given applied micro/nanofluidic problem.	SD_U1, SD_U7	project evaluation, presentation evaluation
U02	Can apply optimization methods for elaboration of the micro/nano composites with lightweight design, micro/nanofluids with optimal thermal properties, and smart coatings.	SD_U1, SD_U2, SD_U3	project evaluation, presentation evaluation
U03	Can gain basic abilities of simulation methods as a fundamental research methodology in micro/nanosciences.	SD_U1, SD_U2	project evaluation, presentation evaluation
	Social competences		
K01	Can work efficiently in small groups working on the same research topic, including the international research groups.	SD_K3, SD_K4, SD_K5	presentation evaluation
K02	Can understand the economic and societal impact of modern nanosciences in aerospace engineering, marine engineering, thermal engineering and material sciences.	SD_K2, SD_K3, SD_K5	presentation evaluation

*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

Passing grade for the lecture tests and practical (laboratory) projects. Grading scale: 3.0 (satisfactory), 3.5 (fairly good), 4.0 (good), 4.5 (very good), 5.0 (excellent).

6. Literature
[1] Course materials provided by the lecturer. [2] Recent scientific publications and reports recommended by the lecturer.

7. PhD student's workload necessary to achieve the learning outcomes**		
No.	Description	Number of hours
1	Contact hours with the academic teacher as part of consultations, exams, tests, etc.	10
2	Hours of independent work of a doctoral student in preparation for classes and preparation of reports, projects, presentations, reports, homework	6
3	Hours of independent work of a doctoral student in preparation for an exam, test, credit	18
4	Contact hours with an academic teacher resulting from the plan	26
	Total number of hours	**60**
	ECTS credits	**2**

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

8. Additional information	
Number of ECTS credits for classes requiring direct participation of academic teachers	
Number of ECTS credits earned by a student in a practical course	