

## SYLLABUS OF A MODULE

Polish name of a module	<b>FIZYCZNE PODSTAWY SZTUCZNEJ INTELIGENCJI</b>
English name of a module	<b>PHYSICAL FOUNDATIONS OF ARTIFICIAL INTELLIGENCE</b>
ISCED classification - Code	0613
ISCED classification - Field of study	Software and applications development and analysis
Languages of instruction	English
Level of qualification	first level
Number of ECTS credit points	3
Examination	assignment
Available in semester	spring

### Number of hours per semester:

Lecture	Tutorial	Laboratory	Seminar	Project	Others
30	15	0	0	0	0

### **MODULE DESCRIPTION**

#### **MODULE OBJECTIVES**

O1. Understanding the laws of physics as they apply to artificial intelligence technologies.

#### **PRELIMINARY REQUIREMENTS FOR KNOWLEDGE, SKILLS AND OTHER COMPETENCES**

1. Basic mathematical skills, especially in algebra and trigonometry, as they are necessary for understanding physics formalisms

#### **LEARNING OUTCOMES**

**LO1** – gain understanding of the physical principles that underlie modern artificial intelligence technologies, enabling them to appreciate how fundamental physics contributes to the development and operation of AI systems

**LO2** – explore how physical laws and phenomena are applied in AI, particularly in areas such as machine learning algorithms, neural networks, robotics, and quantum computing, thus preparing students to innovate at the intersection of these fields

**MODULE CONTENT**

Form – LECTURE	Number of hours
<p><b>L1 Classical Mechanics – Part 1</b></p> <p><b>1. Topics Covered:</b></p> <ul style="list-style-type: none"> <li>a. Introduction to physical quantities, measurement and SI base units.</li> <li>b. Introduction to classical mechanics and its relevance to AI.</li> <li>c. Point kinematics: motion in one, two, and three dimensions.</li> <li>d. Newton’s laws of motion and their application to AI-controlled systems.</li> <li>e. Dynamics: force, mass, acceleration, and their role in robotics.</li> <li>f. Work, energy, and power: conservation laws in AI systems.</li> </ul> <p><b>AI Connection: classical mechanics principles applied in AI-driven robotics, such as the dynamics of robotic arms and autonomous vehicles.</b></p>	<p><b>2</b></p>
<p><b>L2 Classical Mechanics – Part 2</b></p> <p><b>1. Topics Covered:</b></p> <ul style="list-style-type: none"> <li>a. Conservation of momentum and angular momentum.</li> <li>b. Collisions and their relevance in AI (e.g., obstacle detection and avoidance).</li> <li>c. Rigid body dynamics: rotational motion, torque, and angular momentum in robotic systems.</li> <li>d. Stability and control in AI systems using rigid body dynamics.</li> </ul>	<p><b>2</b></p>

<p><b>AI Connection: rigid body dynamics are crucial in AI, such as drones, balance in robots, and gyroscopic control.</b></p>	
<p><b>L3 Thermodynamics – Part 1</b></p> <p><b>1. Topics Covered:</b></p> <ul style="list-style-type: none"> <li>a. Introduction to thermodynamics and its significance in AI.</li> <li>b. Laws of thermodynamics and energy transformations.</li> <li>c. Ideal gas law and its applications in AI, especially in sensor technologies.</li> <li>d. Heat engines, refrigerators, and the Carnot cycle.</li> </ul> <p><b>AI Connection: thermodynamic efficiency of AI hardware, such as processors and sensors, and the role of energy conservation in AI-driven systems.</b></p>	<p><b>2</b></p>
<p><b>L4 Thermodynamics – Part 2</b></p> <p><b>1. Topics Covered:</b></p> <ul style="list-style-type: none"> <li>a. Entropy, disorder, and information theory in AI.</li> <li>b. Thermodynamic transformations and transitions.</li> <li>c. Introduction to statistical mechanics: microstates, macrostates, and the Boltzmann distribution.</li> <li>d. Application of statistical mechanics to AI, such as in probabilistic models and machine learning.</li> </ul> <p><b>AI Connection: entropy is used in information theory, a foundational concept in machine learning algorithms.</b></p>	<p><b>2</b></p>
<p><b>L5 Elements of Electrodynamics – Part 1</b></p> <p><b>1. Topics Covered:</b></p> <ul style="list-style-type: none"> <li>a. Electric potential, current, and energy in AI circuits.</li> <li>b. Resistance, capacitance, and inductance: basics for AI hardware.</li> <li>c. Circuit analysis: Kirchhoff's laws and their applications in AI hardware design.</li> </ul> <p><b>AI Connection: the role of electrodynamics in the design and functioning of AI hardware, such as neural network processors and embedded systems.</b></p>	<p><b>2</b></p>
<p><b>L6 Elements of Electrodynamics – Part 2</b></p>	<p><b>2</b></p>

<p><b>1. Topics Covered:</b></p> <ul style="list-style-type: none"> <li>a. Electric and magnetic fields and their significance in AI.</li> <li>b. Lorentz force law and its applications in AI-driven devices.</li> <li>c. Ampere's and Faraday's laws: electromagnetic induction in AI systems.</li> <li>d. Maxwell's equations and their implications for AI, especially in communication and sensing technologies.</li> </ul> <p><b>AI Connection: electromagnetic fields are the basis of AI applications, such as in wireless communication and sensing for autonomous systems.</b></p>	
<p><b>L7 Geometrical and Physical Optics</b></p> <p><b>1. Topics Covered:</b></p> <ul style="list-style-type: none"> <li>a. Basics of geometrical optics: reflection, refraction, and lens systems.</li> <li>b. Physical optics: wave nature of light, diffraction, and interference.</li> <li>c. Application of optics in AI, particularly in vision systems and sensors.</li> </ul> <p><b>AI Connection: optics enables AI systems, including image processing, computer vision, and autonomous vehicle sensors.</b></p>	<b>2</b>
<p><b>L8 Quantum Mechanics – Part 1</b></p> <p><b>1. Topics Covered:</b></p> <ul style="list-style-type: none"> <li>a. Introduction to quantum mechanics and its relevance to AI.</li> <li>b. Wave-particle duality, Heisenberg uncertainty principle, and Schrödinger's equation.</li> <li>c. Quantum states, superposition, and entanglement.</li> </ul> <p><b>AI Connection: applications of quantum mechanics in AI, such as quantum computing and quantum neural networks.</b></p>	<b>2</b>
<p><b>L9 Quantum Mechanics – Part 2</b></p> <p><b>1 Topics Covered:</b></p> <p>Quantum computing fundamentals: qubits, quantum gates,</p>	<b>2</b>

<p>and quantum circuits.</p> <p>Quantum algorithms and their implications for AI.</p> <p>Quantum information theory and cryptography.</p> <p><b>AI Connection: quantum mechanics can revolutionize AI through faster computation and secure data processing.</b></p>	
<p><b>L10 Electrodynamics and Optics in AI systems</b></p> <p><b>1 Topics Covered:</b></p> <p>Advanced applications of Maxwell's equations in AI.</p> <p>Poynting vector and energy flow in AI systems.</p> <p>Advanced optical systems in AI: laser optics, fiber optics, and photonic computing.</p> <p><b>AI Connection: applications of advanced optics and electrostatics in AI, such as in optical computing and AI enhanced communication systems.</b></p>	<b>2</b>
<p><b>L11 Statistical Mechanics for AI algorithms</b></p> <p><b>1. Topics Covered:</b></p> <ol style="list-style-type: none"> <li>a. Detailed study of statistical mechanics in AI systems.</li> <li>b. Application of the Boltzmann distribution in AI algorithms.</li> <li>c. The connection between thermodynamic entropy and information entropy in machine learning.</li> </ol> <p><b>AI Connection: advanced applications of statistical mechanics in AI, such as in deep learning, optimization algorithms, and neural network training.</b></p>	<b>2</b>
<p><b>L12 Thermodynamics in AI models</b></p> <ul style="list-style-type: none"> <li>• <b>Topics Covered:</b> <ul style="list-style-type: none"> <li>○ Advanced topics in thermodynamics relevant to AI.</li> <li>○ Energy efficiency in AI hardware and software.</li> <li>○ Thermodynamic constraints on AI system performance.</li> </ul> </li> </ul> <p><b>AI Connection: thermodynamics limits and optimizes AI system design, with a focus on energy-efficient AI and sustainable computing.</b></p>	<b>2</b>
<p><b>L13 Electromagnetic Fields and Signal Theory</b></p> <ul style="list-style-type: none"> <li>• <b>Topics Covered:</b></li> </ul>	<b>2</b>

<ul style="list-style-type: none"> <li>○ Role of electromagnetic fields in AI communication systems.</li> <li>○ Electromagnetic spectrum and its applications in wireless AI systems.</li> <li>○ Advanced topics in AI communication: RF, microwave, and optical communication technologies.</li> </ul> <p><b>AI Connection: integration of AI in communication systems, focusing on the electromagnetic principles that enable wireless networks, autonomous vehicle communication, and AI in IoT.</b></p>	
<p><b>L14 Quantistic Models and Quantum Neural Networks</b></p> <p><b>1. Topics Covered:</b></p> <ul style="list-style-type: none"> <li>a. Latest advancements in quantum computing and their implications for AI.</li> <li>b. Quantum machine learning: algorithms and applications.</li> <li>c. Future prospects of quantum AI and the challenges ahead.</li> </ul> <p><b>AI Connection: current research and applications in quantum AI, focusing on how quantum mechanics could redefine the future of artificial intelligence.</b></p>	<b>2</b>
<p><b>L15 Summary and final test</b></p>	<b>2</b>
<p><b>Form – EXERCISES</b></p>	<b>Number of hours</b>
<p><b>Ex1 Mechanics in AI Systems</b></p> <p><b>1. Practical Exercises:</b></p> <ul style="list-style-type: none"> <li>1. Solve problems on the motion of AI-controlled objects using kinematic equations.</li> <li>2. <b>Analyze a simple robotic system using Newton’s laws and energy conservation principles.</b></li> </ul>	<b>1</b>
<p><b>Ex2 Rigid Body Dynamics in AI</b></p> <p><b>1. Practical Exercises:</b></p> <ul style="list-style-type: none"> <li>a. Problems on rotational motion and torque in AI-driven systems.</li> </ul>	<b>1</b>

<p>b. <b>Simulate and analyze the stability of a robot using concepts of angular momentum.</b></p>	
<p><b>Ex3 Thermodynamic Applications in AI</b></p> <p>1. <b>Practical Exercises:</b></p> <p>a. Solve problems on energy efficiency and heat transfer in AI hardware.</p> <p>b. <b>Analyze the energy consumption of an AI system using the laws of thermodynamics.</b></p>	<p><b>1</b></p>
<p><b>Ex4 Entropy and Information Theory in AI</b></p> <p>1. <b>Practical Exercises:</b></p> <p>a. Problems on calculating entropy in thermodynamic systems.</p> <p>b. <b>Application of entropy in information theory, with exercises on data compression and loss functions in machine learning.</b></p>	<p><b>1</b></p>
<p><b>Ex5 Circuit Analysis for AI Systems</b></p> <p>1. <b>Practical Exercises:</b></p> <p>a. Solve circuit problems involving resistors, capacitors, and inductors in AI systems.</p> <p>b. Design a simple circuit relevant to AI applications, such as a sensor network.</p>	<p><b>1</b></p>
<p><b>Ex6 Electromagnetic Fields in AI</b></p> <p>1. <b>Practical Exercises:</b></p> <p>a. Analyze problems involving electromagnetic fields in AI systems.</p> <p>b. Simulate the impact of electromagnetic fields on AI sensors and communication devices.</p>	<p><b>1</b></p>
<p><b>Ex7 Optics in AI Vision Systems</b></p> <p>1. <b>Practical Exercises:</b></p> <p>a. Solve problems related to the design of optical systems for AI applications.</p> <p>b. Analyze optical phenomena in AI-based vision systems, such as lens distortions and light diffraction.</p>	<p><b>1</b></p>

<p><b>Ex8 Quantum Mechanics in AI</b></p> <p><b>1. Practical Exercises:</b></p> <ul style="list-style-type: none"> <li>a. Solve basic quantum mechanics problems with applications to AI.</li> <li>b. Simulate quantum states and their use in quantum algorithms for AI.</li> </ul>	<b>1</b>
<p><b>Ex9 Quantum Computing and AI</b></p> <p><b>1. Practical Exercises:</b></p> <ul style="list-style-type: none"> <li>a. Develop simple quantum circuits and analyze their potential applications in AI.</li> <li>b. Explore quantum algorithms like Grover's and their implications for AI problem-solving.</li> </ul>	<b>1</b>
<p><b>Ex10 Advanced Applications in AI</b></p> <p><b>1. Practical Exercises:</b></p> <ul style="list-style-type: none"> <li>a. Problems on energy flow and Poynting vectors in AI devices.</li> <li>b. Design and analysis of advanced optical systems for AI, such as photonic circuits.</li> </ul>	<b>1</b>
<p><b>Ex11 Statistical Mechanics in AI Algorithms</b></p> <p><b>1. Practical Exercises:</b></p> <ul style="list-style-type: none"> <li>a. Solve problems on applying statistical mechanics to machine learning models.</li> <li>b. Analyze entropy-based regularization techniques in AI algorithms.</li> </ul>	<b>1</b>
<p><b>Ex12 Energy Efficiency in AI</b></p> <p><b>1. Practical Exercises:</b></p> <ul style="list-style-type: none"> <li>a. Analyze energy consumption in AI algorithms.</li> <li>b. Design strategies for optimizing AI systems for energy efficiency.</li> </ul>	<b>1</b>
<p><b>Ex13 AI in Communication Systems</b></p> <p><b>1. Practical Exercises:</b></p> <ul style="list-style-type: none"> <li>a. Solve problems related to electromagnetic fields in AI communication systems.</li> </ul>	<b>1</b>

b. Simulate AI-driven communication systems and analyze their efficiency.	
<b>Ex14 Simulating Quantum AI</b> 1. <b>Practical Exercises:</b> a. Develop and simulate quantum algorithms for AI applications. b. Analyze the potential and limitations of current quantum AI technologies.	<b>1</b>
<b>Ex15 Colloquium</b>	<b>1</b>

### TEACHING TOOLS

1. – Audiovisual media, multimedia presentations
2. – Physics Experiment Demonstration Kits
3. – E-learning CUT platform

### WAYS OF ASSESSMENT ( F – FORMATIVE, S – SUMMATIVE

<b>F1</b> – assessment of independent preparation for classes
<b>S1</b> –test
<b>S2</b> - colloquium

\*) in order to receive a credit for the module, the student is obliged to attain a passing grade in all laboratory classes as well as in achievement tests.

### STUDENT'S WORKLOAD

L.p	Forms of activity	Average number of hours required for realization of activity
<b>1. Contact hours with teacher</b>		
1.1	Lectures	30
1.2	Tutorials	15
1.3	Laboratory	
1.4	Seminar	
1.5	Project	
1.6	Examination	

Total number of contact hours with teacher:		45
<b>1. Student's individual work</b>		
2.1	Preparation for tutorials and tests	12
2.2	Prreparation for laboratory exercises, writing reports on laboratories	0
2.3	Preparation of project	0
2.4	Preparation for final lecture assessment	9
2.5	Preparation for examination	0
2.6	Individual study of literature	9
Total numer of hours of student's individual work:		30
Overall student's workload:		75
<b>Overall number of ECTS credits for the module</b>		<b>3</b>
Number of ECTS points that student receives in classes requiring teacher's supervision:		1,8
Number of <b>ECTS</b> credits acquired during practical classes including laboratory exercises and projects :		1,1

### **BASIC AND SUPPLEMENTARY RESOURCE MATERIALS**

D. Halliday, R. Resnick (& J. Walker) - Fundamentals of Physics vol. 1
D. Halliday, R. Resnick (& J. Walker) - Fundamentals of Physics vol. 2
J.R. Taylor – Classical Mechanics
D.J. Griffiths - Introduction to Electrodynamics
J.J.Sakurai - Modern Quantum Mechanics
Brociek, R.; Hetmaniok, E.; Napoli, C.; Capizzi, G.; Slota, D. 2024 Identification of aerothermal heating for thermal protection systems taking into account the thermal resistance between layers. In INTERNATIONAL JOURNAL OF HEAT AND MASS TRANSFER vol. 218. DOI: 10.1016/j.ijheatmasstransfer.2023.124772. 200 pkt.
Grycuk, R.; De Magistris, G.; Napoli, C.; Scherer, R. 2024 Toward Real-Time Solar Content-Based Image Retrieval. DOI: 10.1007/978-3-031-63749-0_8. In Computational Science – ICCS 2024. 24th International Conference, Malaga, Spain, July 2–4, 2024, Proceedings, Part I - ISBN: 9783031637483. In LECTURE NOTES IN COMPUTER SCIENCE vol. 14832. 140 pkt.

**MODULE COORDINATOR (NAME, SURNAME, DEPARTMENT, E-MAIL ADDRESS)**

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