

## Subject card

|                                             |                                                       |                                                          |                                         |                                     |         |                                                                                                                                                |     |
|---------------------------------------------|-------------------------------------------------------|----------------------------------------------------------|-----------------------------------------|-------------------------------------|---------|------------------------------------------------------------------------------------------------------------------------------------------------|-----|
| Subject name and code                       | Field Theory, PG_00182569                             |                                                          |                                         |                                     |         |                                                                                                                                                |     |
| Field of study                              | Physics                                               |                                                          |                                         |                                     |         |                                                                                                                                                |     |
| Date of commencement of studies             | October 2025                                          |                                                          | Academic year of realisation of subject |                                     |         | 2025/2026                                                                                                                                      |     |
| Education level                             | Master's studies                                      |                                                          | Subject group                           |                                     |         | Obligatory subject group in the field of study<br>Optional subject group<br>Subject group related to scientific research in the field of study |     |
| Mode of study                               | full-time studies                                     |                                                          | Mode of delivery                        |                                     |         | at the university                                                                                                                              |     |
| Year of study                               | 1                                                     |                                                          | Language of instruction                 |                                     |         | Polish<br>If there is a student or lecturer who does not speak Polish, the lecture is conducted in English.                                    |     |
| Semester of study                           | 1                                                     |                                                          | ECTS credits                            |                                     |         | 8.0                                                                                                                                            |     |
| Learning profile                            | academic                                              |                                                          | Assessment form                         |                                     |         | exam                                                                                                                                           |     |
| Conducting unit                             |                                                       |                                                          |                                         |                                     |         |                                                                                                                                                |     |
| Name and surname of lecturer (lecturers)    | Subject supervisor                                    |                                                          | prof. dr hab. Michał Horodecki          |                                     |         |                                                                                                                                                |     |
|                                             | Teachers                                              |                                                          |                                         |                                     |         |                                                                                                                                                |     |
| Lesson types                                | Lesson type                                           | Lecture                                                  | Tutorial                                | Laboratory                          | Project | Seminar                                                                                                                                        | SUM |
|                                             | Number of study hours                                 | 45.0                                                     | 45.0                                    | 0.0                                 | 0.0     | 0.0                                                                                                                                            | 90  |
|                                             | E-learning hours included: 0.0                        |                                                          |                                         |                                     |         |                                                                                                                                                |     |
| Learning activity and number of study hours | Learning activity                                     | Participation in didactic classes included in study plan |                                         | Participation in consultation hours |         | Self-study                                                                                                                                     | SUM |
|                                             | Number of study hours                                 | 90                                                       |                                         | 0.0                                 |         | 110.0                                                                                                                                          | 200 |
| Subject objectives                          | Learning basics of quantum and classical field theory |                                                          |                                         |                                     |         |                                                                                                                                                |     |

| Learning outcomes               | Course outcome                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | Subject outcome                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | Method of verification                                                                                                 |
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|                                 | [FIZMU2_W01] has advanced knowledge of general physics and in-depth knowledge of various areas of physics; knows the history of the development of physics and its importance for the progress of exact and natural sciences, cognition of the world and social development                                                                                                                                                                                                                                                                                                                       | W1: The student knows the Lagrangian formalism in field theory and understands the application of Noether's theorem to conservation laws.<br>W2: The student has advanced knowledge of scalar, spinor, and vector fields and their role in relativistic field theory.<br>W3: The student is familiar with the fundamentals of many-body theory: second quantization, Green's functions, approximations, and diagrammatic methods.<br>W4: The student understands the process of field quantization, the spin-statistics connection, the construction of the S-matrix, and renormalization methods. | [SW4] test/exam - oral or written<br>[SW2] presentation/project/paper/report<br>[SW3] text preparation/written work    |
|                                 | [FIZMU2_U09] can work independently or in a team                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | The student prepares a term paper in the field of classical field theory; delivers a seminar on many-body theory; and takes an exam consisting of problems testing the understanding of field quantization, Feynman diagrams, and scattering amplitudes for interacting fields                                                                                                                                                                                                                                                                                                                     | [SU2] presentation/project/paper/report<br>[SU3] text preparation/written work<br>[SU4] test/exam - oral or written    |
|                                 | [FIZMU2_W02] has in-depth knowledge in mathematics as well as mathematical and computational methods, necessary to solve physical problems of high complexity and in-depth in the selected area of physics                                                                                                                                                                                                                                                                                                                                                                                        | The student becomes acquainted with various mathematical methods applied to physics, such as Lie group representations, the formalism of creation and annihilation operators, the Green's function formalism, and Feynman diagrams.                                                                                                                                                                                                                                                                                                                                                                | [SW4] test/exam - oral or written<br>[SW2] presentation/project/paper/report<br>[SW5] implementation of a problem task |
|                                 | [FIZMU2_K01] knows the limitations of his own knowledge and skills; can formulate questions precisely; understands the need for further education and other                                                                                                                                                                                                                                                                                                                                                                                                                                       | K1: The student is aware of the importance of rigorous mathematical foundations in describing physical phenomena and can critically evaluate results.<br>K2: The student understands the significance of field theory and many-body theory as the foundations of modern theoretical physics and is prepared to further develop knowledge in this field.                                                                                                                                                                                                                                            | [SK2] presentation/project/paper/report<br>[SK3] text preparation/written work<br>[SK4] test/exam - oral or written    |
|                                 | [FIZMU2_U01] is able to apply the scientific method in solving physical problems, conducting experiments and reasoning                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | FIZMU2_U01 U1: The student can apply the formalism of second quantization and Green's functions to analyze many-body systems.<br>U2: The student can perform basic calculations in quantum field theory, including the use of Feynman diagrams and renormalization methods.<br>U3: The student can analyze the Lagrangian of the Standard Model and identify symmetries and mass generation mechanisms.                                                                                                                                                                                            | [SU2] presentation/project/paper/report<br>[SU3] text preparation/written work<br>[SU4] test/exam - oral or written    |
| Subject contents                | 1. Relativistic classical field theory: Lagrangian formalism, Noethers theorem, scalar, spinor, and vector fields; internal symmetries, gauge field theory, spontaneous symmetry breaking, mass generation, Lagrangian of the Standard Model.<br>2. Many-body theory: second quantization, Greens functions, exactly solvable fermionic model, Feynman diagrams for the electron gas with Coulomb interaction, divergences, random phase approximation.<br>3. Field quantization: relativistic quantum free fields, spinstatistics theorem (sketch), S-matrix, Feynman diagrams, renormalization. |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                                                                                        |
| Prerequisites and co-requisites | Knowledge of quantum mechanics, classical mechanics in the Lagrangian formulation, and classical electrodynamics.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                                                                                        |
| Assessment methods and criteria | Subject passing criteria                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Passing threshold                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | Percentage of the final grade                                                                                          |
|                                 | term paper                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | 51.0%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 34.0%                                                                                                                  |
|                                 | presentation                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | 51.0%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 33.0%                                                                                                                  |
|                                 | written exam                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | 51.0%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 33.0%                                                                                                                  |

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| Recommended reading                                            | Basic literature         | <p>1. No-Nonsense Quantum Field Theory: A Student-Friendly Introduction, Jakob Schwichtenberg</p> <p>2. Quantum Field Theory for the Gifted Amateur, by Tom Lancaster, Stephen J. Blundell</p> <p>3. An Introduction To Quantum Field Theory, Michael E. Peskin, Daniel V. Schroeder</p> <p>4. Many-body quantum theory in condensed matter physics, Henrik Bruus and Karsten Flensberg</p> |
|                                                                | Supplementary literature | <p>1. A Modern Introduction to Quantum Field Theory, Michele Maggiore</p> <p>2. Quantum Theory of Many-particle Systems, Alexander L. Fetter, John Dirk Walecka</p>                                                                                                                                                                                                                         |
|                                                                | eResources addresses     | <p>Supplementary</p> <p><a href="https://www.youtube.com/watch?v=qBoNQJdl4Qc&amp;t=69s">https://www.youtube.com/watch?v=qBoNQJdl4Qc&amp;t=69s</a> - youtube: Luis Gregorio Dias, Course on Quantum Many-Body Physics. Note: the provided link is to the first lecture. For the course, the entire lecture series is relevant, except for the lectures on interaction with phonons.</p>      |
| Example issues/<br>example questions/<br>tasks being completed |                          |                                                                                                                                                                                                                                                                                                                                                                                             |
| Work placement                                                 | Not applicable           |                                                                                                                                                                                                                                                                                                                                                                                             |

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