

## DESCRIPTION OF THE COURSE OF STUDY

|                       |                   |                                    |
|-----------------------|-------------------|------------------------------------|
| Course code           | 0533.6.FIZ2.D.RQM |                                    |
| Name of the course in | Polish            | Relatywistyczna mechanika kwantowa |
|                       | English           | Relativistic quantum mechanics     |

## 1. LOCATION OF THE COURSE OF STUDY WITHIN THE SYSTEM OF STUDIES

|                                                |                                 |
|------------------------------------------------|---------------------------------|
| 1.1. Field of study                            | Physics                         |
| 1.2. Mode of study                             | Stationary                      |
| 1.3. Level of study                            | Second-cycle studies            |
| 1.4. Profile of study*                         | General academic                |
| 1.5. Person/s preparing the course description | prof. dr hab. Francesco Giacosa |
| 1.6. Contact                                   | francesco.giacosa@ujk.edu.pl    |

## 2. GENERAL CHARACTERISTICS OF THE COURSE OF STUDY

|                              |                                                                                                   |
|------------------------------|---------------------------------------------------------------------------------------------------|
| 2.1. Language of instruction | English                                                                                           |
| 2.2. Prerequisites*          | Knowledge of classical physics, quantum mechanics and mathematics at the Bachelor's degree level. |

## 3. DETAILED CHARACTERISTICS OF THE COURSE OF STUDY

|                                                    |                  |                                                                                                                                                                                                                                                                                                                                                     |
|----------------------------------------------------|------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 3. DETAILED CHARACTERISTICS OF THE COURSE OF STUDY |                  |                                                                                                                                                                                                                                                                                                                                                     |
| 3.1. Form of classes                               |                  | Lectures (L)                                                                                                                                                                                                                                                                                                                                        |
| 3.2. Place of classes                              |                  | Institute of Physics UJK                                                                                                                                                                                                                                                                                                                            |
| 3.3. Form of assessment                            |                  | Credit with a grade                                                                                                                                                                                                                                                                                                                                 |
| 3.4. Teaching methods                              |                  | Oral lectures, problem solving                                                                                                                                                                                                                                                                                                                      |
| 3.5. Bibliography                                  | Required reading | - Zee, <i>Quantum Field Theory in a Nutshell</i> , 2nd ed., Princeton University Press, Princeton, 2010<br>- F. Mandl, G. Shaw, <i>Quantum Field Theory</i> , 2nd ed., John Wiley & Sons, Chichester, 2010.                                                                                                                                         |
|                                                    | Further reading  | -Zee, <i>Group Theory in a Nutshell for Physicists</i> , Princeton University Press, Princeton, 2016.<br>-F. Halzen, A. D. Martin, <i>Quarks and Leptons: An Introductory Course in Modern Particle Physics</i> , John Wiley & Sons, New York, 1984..<br>-M. Thomson, <i>Modern Particle Physics</i> , Cambridge University Press, Cambridge, 2013. |

## 4. OBJECTIVES, SYLLABUS CONTENT AND INTENDED LEARNING OUTCOMES

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| <b>4.1. Course objectives (including form of classes)</b><br>1. Description of the most important features and formalism of relativistic Quantum Mechanics.<br>2. Understanding the mathematical tools related to of relativistic Quantum Mechanics.<br>3. Developing skills to solve exercises and to understand the ongoing research on these topics.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| <b>4.2. Detailed syllabus (including form of classes)</b><br>(1) Review of quantum mechanics: states, operators, observables, and the Schrödinger equation.<br>(2) Review of special relativity: Lorentz transformations, four-vectors, and relativistic energy and momentum.<br>(3) From the Schrödinger equation to relativistic quantum mechanics: the Klein–Gordon and Dirac equations.<br>(4) The necessity of a quantum-field description: particle creation and annihilation.<br>(5) Scalar fields: Lagrangian formulation, quantization, and creation and annihilation operators.<br>(6) Scalar fields: applications to particle decays and scattering processes.<br>(7) Vector fields: the Proca equation and applications to particle decays, including $\rho \rightarrow \pi\pi$ .<br>(8) The photon field: gauge invariance and electromagnetic interactions.<br>(9) Fermion fields: quantization and applications to scattering and decay processes.<br>(10) Tensor fields: tensor mesons and an introduction to the graviton. |

## 4.3 Intended learning outcomes

|      |                                  |                               |
|------|----------------------------------|-------------------------------|
| Code | A student, who passed the course | Relation to learning outcomes |
|------|----------------------------------|-------------------------------|

| within the scope of <b>KNOWLEDGE:</b>         |                                                                                                                                               |                                       |
|-----------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------|
| W01                                           | Knows and understands the fundamental concepts and formalism of relativistic quantum mechanics                                                | FIZ2A_W01,<br>FIZ2A_W02,<br>FIZ2A_W03 |
| within the scope of <b>ABILITIES:</b>         |                                                                                                                                               |                                       |
| U01                                           | Is able to apply appropriate mathematical methods to solve problems in relativistic quantum mechanics.                                        | FIZ2A_U02                             |
| U02                                           | Is able to present and discuss topics of general interest, such as the nature of bosons, fermions, and particle creations.                    | FIZ2A_U07                             |
| within the scope of <b>SOCIAL COMPETENCE:</b> |                                                                                                                                               |                                       |
| K01                                           | Is ready to critically assess and expand his/her knowledge of contemporary topics in relativistic quantum mechanics and quantum field theory. | FIZ2A_K02                             |

| 4.4. Methods of assessment of the intended learning outcomes |                             |   |     |                 |   |     |                 |   |     |                 |   |     |                 |   |     |                 |   |     |                                                      |   |     |
|--------------------------------------------------------------|-----------------------------|---|-----|-----------------|---|-----|-----------------|---|-----|-----------------|---|-----|-----------------|---|-----|-----------------|---|-----|------------------------------------------------------|---|-----|
| Teaching outcomes<br>(code)                                  | Method of assessment (+/-)  |   |     |                 |   |     |                 |   |     |                 |   |     |                 |   |     |                 |   |     |                                                      |   |     |
|                                                              | Written and oral assessment |   |     | Test            |   |     | Project         |   |     | Effort in class |   |     | Self-study      |   |     | Group work      |   |     | Others*<br>e.g. standardized test used in e-learning |   |     |
|                                                              | Form of classes             |   |     | Form of classes |   |     | Form of classes |   |     | Form of classes |   |     | Form of classes |   |     | Form of classes |   |     | Form of classes                                      |   |     |
|                                                              | L                           | C | ... | L               | C | ... | L               | C | ... | L               | C | ... | L               | C | ... | L               | C | ... | L                                                    | C | ... |
| W01                                                          | x                           |   |     |                 |   |     |                 |   |     |                 |   |     |                 |   |     |                 |   |     |                                                      |   |     |
| U01                                                          | x                           |   |     |                 |   |     |                 |   |     |                 |   |     |                 |   |     |                 |   |     |                                                      |   |     |
| U02                                                          | x                           |   |     |                 |   |     |                 |   |     |                 |   |     |                 |   |     |                 |   |     |                                                      |   |     |
| K01                                                          | x                           |   |     |                 |   |     |                 |   |     |                 |   |     |                 |   |     |                 |   |     |                                                      |   |     |

| 4.5. Criteria of assessment of the intended learning outcomes |       |                                       |
|---------------------------------------------------------------|-------|---------------------------------------|
| Form of classes                                               | Grade | Criterion of assessment               |
| lecture (L)                                                   | 3     | 51-60% of the total points available  |
|                                                               | 3,5   | 61-70% of the total points available  |
|                                                               | 4     | 71-80% of the total points available  |
|                                                               | 4,5   | 81-90% of the total points available  |
|                                                               | 5     | 91-100% of the total points available |

## 5. BALANCE OF ECTS CREDITS – STUDENT’S WORK INPUT

| Category                                                                     | Student's workload |                    |
|------------------------------------------------------------------------------|--------------------|--------------------|
|                                                                              | Full-time studies  | Extramural studies |
| NUMBER OF HOURS WITH THE DIRECT PARTICIPATION OF THE TEACHER /CONTACT HOURS/ | 15                 |                    |
| Participation in lectures                                                    | 15                 |                    |
| INDEPENDENT WORK OF THE STUDENT/NON-CONTACT HOURS/                           | 10                 |                    |
| Preparation for the lecture                                                  | 5                  |                    |
| Preparation for the assessment                                               | 5                  |                    |
| TOTAL NUMBER OF HOURS                                                        | 25                 |                    |
| ECTS credits for the course of study                                         | 1                  |                    |

**Accepted for execution** (date and legible signatures of the teachers running the course in the given academic year)

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