**SYLLABUS**

**regarding the qualification cycle FROM 2023TO 2024**

1. Basic Course/Module Information

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| Course/Module title | Nuclear and high energy physics |
| Course/Module code \* |  |
| Faculty (name of the unit offering the field of study) | College of Natural Sciences |
| Name of the unit running the course | Institute of Physics |
| Field of study | Physics |
| Qualification level | Second-cycle studies |
| Profile |  |
| Study mode | Full-time |
| Year and semester of studies | Year 1, winter or summer semester |
| Course type |  |
| Language of instruction | English |
| Coordinator | dr hab. Marta Łuszczak, prof. UR |
| Course instructor | dr hab. Marta Łuszczak, prof. UR |

\* - as agreed at the faculty

1.1.Learning format – number of hours and ECTS credits

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Semester  (n0.) | Lectures | Classes | Colloquia | Lab classes | Seminars | Practical classes | Internships | others | **ECTS credits** |
| 1 |  | 30 |  |  |  |  |  |  | **5** |

1.2. Course delivery methods

x conducted in a traditional way

x involving distance education methods and techniques (in the case of an epidemic threat)

1.3. Course/Module assessment (exam, pass with a grade, pass without a grade)

exam, pass with a grade

2. Prerequisites

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| 1. KNOWLEDGE OF CLASSICAL PHYSICS (ADVANCED), CALCULUS (ADVANCED) AND QUANTUM MECHANICS (BASICS).  2. KNOWLEDGE OF ATOMIC AND MOLECULAR PHYSICS (BASICS). |

3. Objectives, Learning Outcomes, Course Content, and Instructional Methods

3.1. Course/Module objectives

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| O1 | THE AIM OF THE COURSE IS TO ACQUAINT STUDENTS WITH SELECTED TOPICS OF MODERN NUCLEAR AND HIGH ENERGY PHYSICS , I.E. NUCLEAR STRUCTURE, STANDARD MODEL OF ELEMENTARY PARTICLES, ACCELERATORS. |

3.2. Course/Module Learning Outcomes (to be completed by the coordinator)

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| --- | --- | --- |
| Learning Outcome | The description of the learning outcome  defined for the course/module | Relation to the degree programme outcomes |
| LO\_01 | The graduate knows and understands in depth the issues related to nuclear physics and high energy physics, as well as its historical development and significance for the progress of the sciences. | K\_W01 |
| LO\_02 | The graduate knows and understands current development directions, the latest discoveries and fundamental dilemmas of modern nuclear and high energy physics. | K\_W06, K\_W07 |
| LO\_03 | The graduate knows and understands current dilemmas associated with discoveries of new elementary particles. | K\_W08 |
| LO\_04 | The graduate is able to critically assess the results of experiments, observations and theoretical calculations, as well as discuss measurement errors. | K\_U02 |
| LO\_05 | The graduate is ready to recognize the limitations of his own knowledge and the need to consult experts in the case of difficulties in solving problems related to nuclear and high energy physics. | K\_K01, K\_K02 |
| LO\_06 | The graduate is ready to systematically familiarize himself with scientific and popular science magazines, basic for physics, in order to broaden and deepen knowledge and develop professional achievements. | K\_K05, K\_K06 |

**3.3. Course content (to be completed by the coordinator)**

1. Lectures

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| Content outline |
| 1. Classification of elementary and fundamental particles (leptons and quarks). Hadrons. Yukawa's theory.  2. Elementary interactions. Properties of weak and strong interactions,  electromagnetic and gravitational. Feynman diagrams.  3. Cross sections.  4. Basic properties of atomic nuclei - components of the atomic nucleus and its properties such as: radius of the atomic nucleus, spin, electric charge, parity, moment magnetic and quadrupole.  5. Binding energy. Methods of determining binding energy. Separation energy.  6. Models of the atomic nucleus: the droplet model, the Fermi gas model, the shell model and quadrupole.  7. The law of radioactive decay.  8. Alpha decays, beta decays and gamma radiation. Mechanisms of alpha decay. Types of decay beta. Gamma radiation - excited states of nuclei.  9. Nuclear reactions. Model of nuclear fission. Chain reactions. Series  Radioactive reactions.  10. Nuclear reactors.  11. Construction of modern particle detectors. Operation of linear accelerators and cyclical; Large Hadron Collider (LHC). Recent experiments conducted on the LHC.  12. Spatial inversion, charge parity, isospin parity and time inversion.  13. CKM matrix.  14. Isospin in a system of two nucleons. Isospin in the pion-nucleon system. Coefficients Clebsch-Gordon for the Pion-Nucleon system.  15. The search for the Higgs particle. |

1. Classes (solving tasks related to the topics discussed in the lectures)

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| Content outline |
| 1. Hadrons and quarks - classification of hadrons, quark model of hadrons.  2. Electromagnetic interactions of leptons and quarks - elementary processes and diagrams Feynman QED, electron scattering on muons, electron scattering on nucleons.  3. Calculation of the amplitude and cross section for the selected Feynman diagram.  4. Basic properties of atomic nuclei.  5. Models of the atomic nucleus: the droplet model, the Fermi gas model, the shell model and quadrupole model.  6. The law of radioactive decay. Dating based on the law of radioactive decay. Measurements of radiation dose.  7. Alpha decays, beta decays and gamma radiation. Mechanisms of alpha decay. Types of decay beta. Gamma radiation - excited states of nuclei.  8. Nuclear reactions.  9. Mandelstam's variables.  10. The latest experiments conducted at the LHC accelerator. |

3.4. Methods of Instruction

e.g.

*Lecture: a problem-solving lecture/a lecture supported by a multimedia presentation/ distance learning*

*Classes: text analysis and discussion/project work (research project, implementation project, practical project)/ group work (problem solving, case study, discussion)/didactic games/ distance learning*

*Laboratory classes: designing and conducting experiments*

1. Lecture

2. Multimedia presentation

3. Solving theoretical and practical computational tasks

4. Discussion

4. Assessment techniques and criteria

4.1 Methods of evaluating learning outcomes

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| Learning outcome | Methods of assessment of learning outcomes (e.g. test, oral exam, written exam, project, report, observation during classes) | Learning format (lectures, classes,…) |
| LO-01 | observation during classes, exam, colloquium | lectures, classes |
| LO-o2 | observation during classes, exam, colloquium | lectures, classes |
| LO-o3 | observation during classes | classes |
| LO-o4 | observation during classes | classes |
| LO-o5 | observation during classes | classes |
| LO-o6 | observation during classes | classes |

4.2 Course assessment criteria

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| 1. Oral response (exercises)  2. Student’s activity in solving tasks exercises:  a. Low 2  b. Average 3  c. High 4  d. Very high 5 |

5. Total student workload needed to achieve the intended learning outcomes

– number of hours and ECTS credits

|  |  |
| --- | --- |
| Activity | Number of hours |
| Scheduled course contact hours | 30 |
| Other contact hours involving the teacher (consultation hours, examinations) | 5 |
| Non-contact hours - student's own work (preparation for classes or examinations, projects, etc.) | 40 |
| Total number of hours | 75 |
| Total number of ECTS credits | 5 |

\* One ECTS point corresponds to 25-30 hours of total student workload

6. Internships related to the course/module

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| --- | --- |
| Number of hours | not applicable |
| Internship regulations and procedures | not applicable |

7. Instructional materials

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| Compulsory literature:  1. Donald H. Perkins, *Introduction to High Energy Physics*, Cambridge University Press, 2000.  2. Brian R. Martin, Graham Shaw, *Nuclear and Particle Physics: An Introduction*, 3rd Edition, Wiley, 2019.  3. Francesco Terranova, *A Modern Primer in Particle and Nuclear Physics*, Oxford University Press, USA, 2022. |
| Complementary literature:  1. Mark Thomson*, Modern Particle Physics*, Cambridge University Press, 2013.  2. David Griffiths, *Introduction to Elementary Particles,* Wiley-VCH, 2008. |

Approved by the Head of the Department or an authorised person