

List of topics (subjects) for candidates willing to pass the entry examination to become the Ph.D. student at the Faculty of Physics and Applied Computer Science

SUBJECTS OF THE FIRST, MORE GENERAL PART OF THE EXAM

1. Fundamentals of classical and relativistic mechanics

- Momentum conservation principle
- Angular momentum conservation principle
- Energy conservation principle
- Galileo and Lorentz transformations
- Time dilatation (also: experimental evidence)
- Mass-energy equivalence (also: experimental evidence)

2. Electromagnetism

- Charge conservation principle (also: experimental evidence)
- Electrostatic field, scalar potential
- Gauss Law for electrostatic and magnetic fields
- Vector potential of magnetic field
- Electric charge in magnetic field (examples of applications)
- Magnetic field – mechanism of creation
- Electromagnetic induction
- Wave equation
- Plane wave

3. Experimental foundations of quantum mechanics

- Photoelectric effect
- Compton effect
- Black-body radiation
- Line atomic spectra
- Electron diffraction on crystal (Davisson-Germer experiment)
- Stern-Gerlach experiment

4. Structure of matter

- Standard model of elementary particles
- Atomic nucleus – model of its structure
- Atom and its structure
- Poly-atomic molecules – mechanism of bonds
- Crystal structure of solids

5. Thermodynamics and statistical physics

- Maxwell distribution
- Boltzmann distribution
- Temperature
- I principle of thermodynamics
- Entropy and II principle of thermodynamics

SUBJECTS OF THE ELECTIVE, MORE DETAILED PART OF THE EXAM

Candidate should choose **one** of the following fields of physics (and its applications)

1. Fundamentals of nuclear physics:

- Elementary particles – the standard model
- Evolution of the Universe (in particular: creation of elements)
- Properties of atomic nuclei and the methods of their investigation
- Nuclear forces, binding energy, models of atomic nucleus
- Radioactive transformations of atomic nuclei
- Natural radioactivity of rocks, waters and air
- Accelerators of charged particles
- Nuclear reactions (in particular: fission and fusion of nuclei)
- Interaction of charged particles, gamma radiation and neutrons with matter
- Detection of charge particles, gamma radiation and neutrons
- Neutron sources
- Applications of nuclear isotopes (chosen examples)

2. Fundamentals of solid state physics:

- Crystallography – basic definitions
- Free-electron model
- Interatomic bonds in solids
- X-ray diffraction
- Phonons
- Electron band-structure
- Semiconductors
- Magnetic properties of matter
- Superconductivity
- Nuclear methods in condensed-matter investigations
- Synchrotron radiation – generation, properties and examples of application
- Basic ideas of new materials: quasicrystals, fullerenes, high-temperature superconductors, conducting polymers, semiconducting nanostructures

3. Fundamentals of theoretical and computational physics:

- Postulates of quantum mechanics – illustrated by examples
- Physical interpretation of wave function
- Quantum stationary states
- Electron spin: experiment and theory
- Quantum statistics: bosons and fermions
- Pauli exclusion principle
- Exchange Interaction
- Laplace and Poisson equations and physical processes described by these equations
- Diffusion equation and physical processes described by this equation
- Simple finite-difference methods of solving equations of classical dynamics
- Physical and numerical foundations of classical molecular dynamics
- The method of simulated annealing
- Monte Carlo methods in numerical integration
- Random number generators

4. Fundamentals of particle interaction and detection techniques:

- Elementary particles – The Standard Model: the matter constituents and interaction mediator bosons. Electroweak unification.
- Relativistic momentum, kinetic energy, total energy, relativistic effects, four-vector formalism and relativistic invariants (e.g. C.M.S.)
- Feynman diagrams formalism.
- Electromagnetic processes (photoelectric effect, Compton effect, pair production, total absorption cross section).
- Strong particle interactions (inelastic scattering).
- Accelerators of charged particles (colliders & fix-target, linear & circular).
- Specific energy loss, Bethe-Bloch formula.
- Elementary principles in particle detection, spectrometry, tracking and calorimetry.
- Fundamental concepts of collider experiments – on the example of LHC experiments (ATLAS, CMS, ALICE, LHCb).
- The working principles of radiation detectors (gaseous detector, scintillation counter, semiconductor detector, photomultiplier).
- Principles of operation of basic semiconductor devices: p-n junction, bipolar transistor, MOS transistor.
- Basic principles of signal processing (signal processing in spectrometric chain, filtering, ENC).