Physicist-Engineer BSc
Nuclear Technologies & Sustainable Energies specialization
Final exam topics

The examinee receives one topic from the CORE SUBJECTS (1–12) and one topic from the SPECIALIZATION SUBJECTS (13–24). The examiners may ask short questions from other topics as well.

A: CORE SUBJECTS

Modern Physics

1 The experimental basis of quantum physics.

2 Structure of the atom, de Broglie waves.

3 Schrödinger equation.

4 Quantum tunneling, harmonic oscillator, hydrogen atom.

5 Particle physics: classification of particles, accelerators.

6 Nuclear fusion, formation of elements.

Nuclear Physics Fundamentals

7 **Basic properties of the atomic nucleus**: result of the Rutherford scattering; nuclear charge distribution and Mott scattering with form factor; measurable quantities (nuclear spin, magnetic moment, electric multipole moments).

8 **Nuclear models**: liquid drop model and the Weizsacker formula, basics of the Shell model.

9 **Radioactive decays**: fundamental definitions, decay chains.

10 **Interaction of radiation with matter**: for heavy and light charged particles; for neutral particles.

11 **Nuclear reaction mechanisms**: direct and compound reactions; neutron activation.

12 **Nuclear fission**: fission product yield, neutron production (prompt and delayed neutrons), fission cross section of U-235 and U-238.

B: SPECIALIZATION SUBJECTS

Monte Carlo Methods

13 **Sampling of discrete and continuous probability distributions.** Monte Carlo sampling of discrete random variables. Sampling of continuous random variables described by probability density functions. The inverse cumulative distribution function method. Neumann's rejection method. Composition methods for sampling from complex distributions. Tabulated sampling methods.

14 **Sampling angular distributions.** Methods for sampling isotropic angular distributions in a plane. Sampling isotropic angular distributions in three dimensions with different methods. Sampling cosine angular distributions with respect to a surface normal.

15 **Monte Carlo simulation of particle transport.** Analog and non-analog Monte Carlo tracking. Monte Carlo parameters associated with particles. Main components of a particle transport code. Collision routines and outgoing direction sampling. Free path length modeling in homogeneous, piecewise homogeneous, and inhomogeneous media (Woodcock method).

16 **Variance reduction techniques in particle transport simulations.** Statistical weight and implicit capture. Source biasing. Importance sampling. Russian roulette. Particle splitting.

Radiation Protection

17 **Radiation dose quantities and health effects.** Definitions of radiation dose quantities. Relationships and connections between physical and biological dose quantities. Health effects of ionizing radiation. Deterministic and stochastic effects. Basic concepts of radiation risk.

18 **Measurement of radiation dose and internal exposure.** Theoretical background of dose and dose rate measurements. Instrumentation and measurement techniques for external dose assessment. Measurement and calculation methods for the determination of internal radiation exposure. Individual and collective dose assessment.

19 **Radiation protection principles and regulatory system.** Axioms and fundamental principles of radiation protection. The system of radiation protection regulation. Elements of the radiation protection planning process. Dose limitation system. Dose limits for occupationally exposed workers and the general public. Limitation of emission and immission.

20 **Natural and artificial radioactivity.** Components of natural radioactivity. External exposure from cosmic and terrestrial radiation. Internal exposure and the significance of radon, including measurement methods. Environmental monitoring and differentiation between natural and artificial components. Sources of artificial radioactivity.

Radiation Detection and Measurement

21 **Gas-filled detectors.** Principle of operation of gas-filled detectors, modes of operation. Applications of gas-filled detectors. Current mode and pulse mode operation. Detector efficiency and dead time. Spectrum and energy resolution.

22 **Scintillation detectors.** Principle of operation of scintillation detectors. Inorganic scintillators. Measurement applications. Fundamentals of liquid scintillation counting and its fields of application.

23 **Semiconductor detectors.** Basics of the operation of semiconductor detectors. Operation and applications of HPGe, Si(Li), PIPS, SDD, and CZT detectors. Gamma-ray spectroscopy with semiconductor detectors. Components of a gamma spectrum.

24 **Special detectors and measurement techniques.** X-ray detectors, types of neutron detectors, Cherenkov detector, thermoluminescent detectors, solid-state track detectors, cloud chamber. Activation analysis, radiography, tomography, neutrino detection.